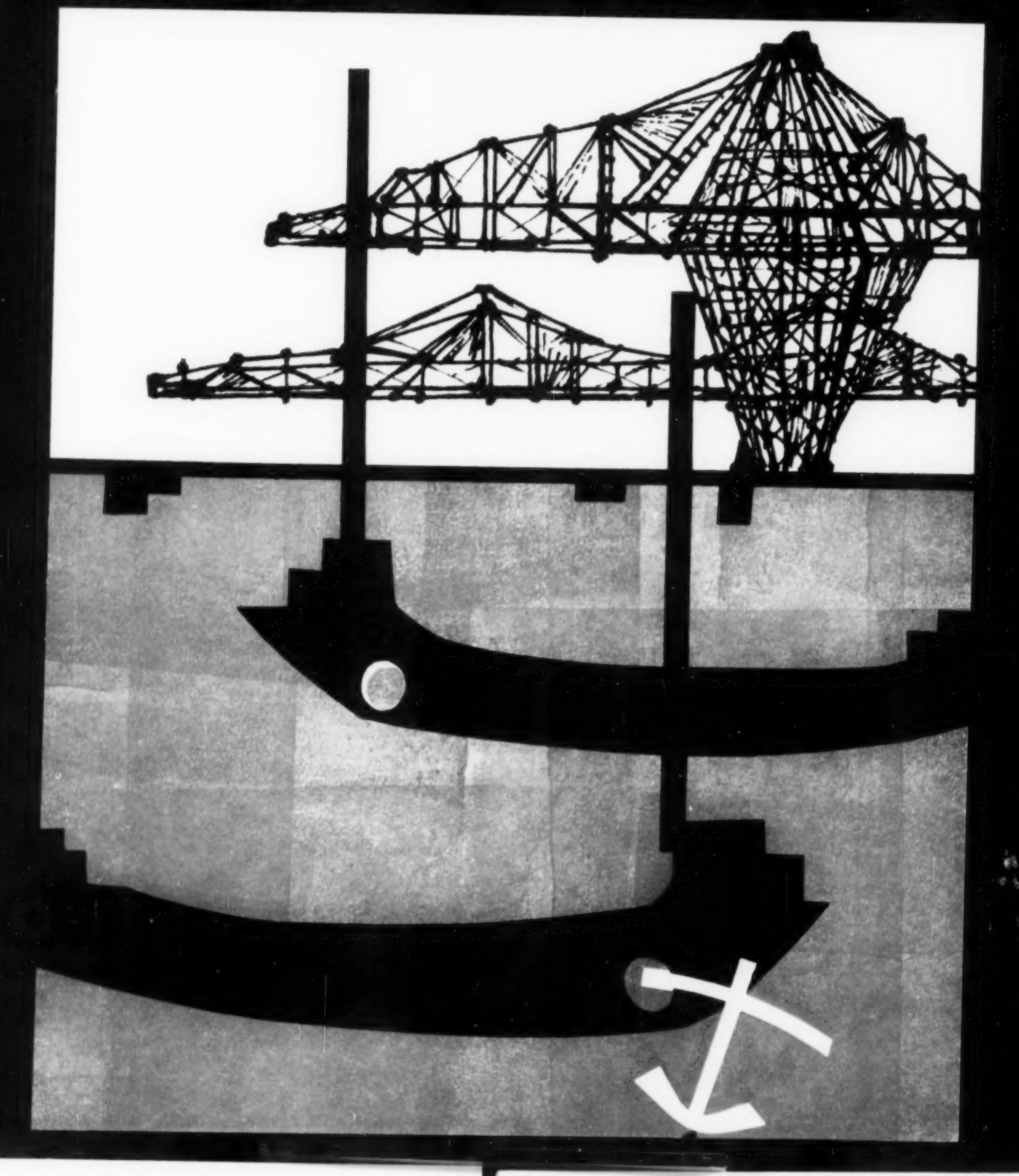
JOURNAL OF

# METALS

NOVEMBER 1957



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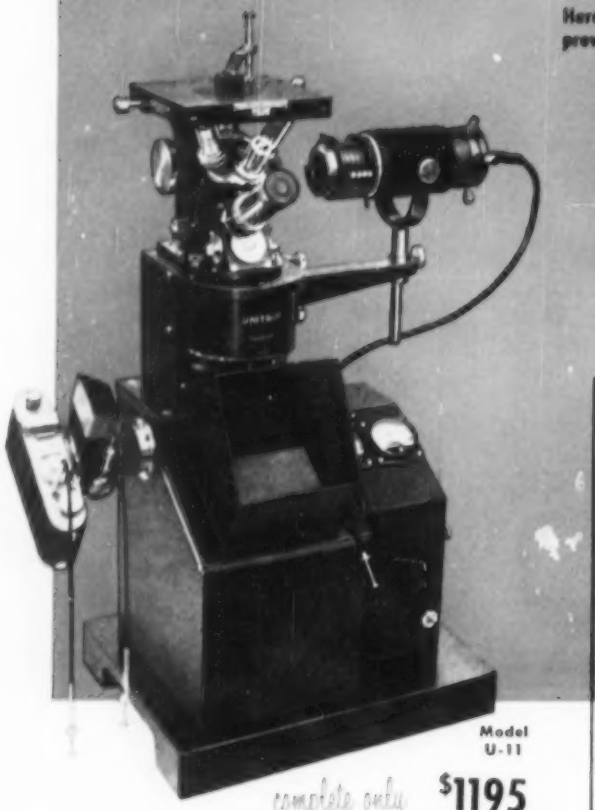

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JOURNAL OF

# METALS

VOL. 9, NO. 11

NOVEMBER, 1957

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## COVER

Ore Ships on the Rhein, main artery for Germany's Ruhr, is the theme of this month's cover by Naomi Lazard. How America helped rebuild one of the Ruhr's large steel mills is told on p. 1426, and articles on two important new German metallurgical developments are found on pp. 1432 and 1435.

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*(Continued on page 1400)*

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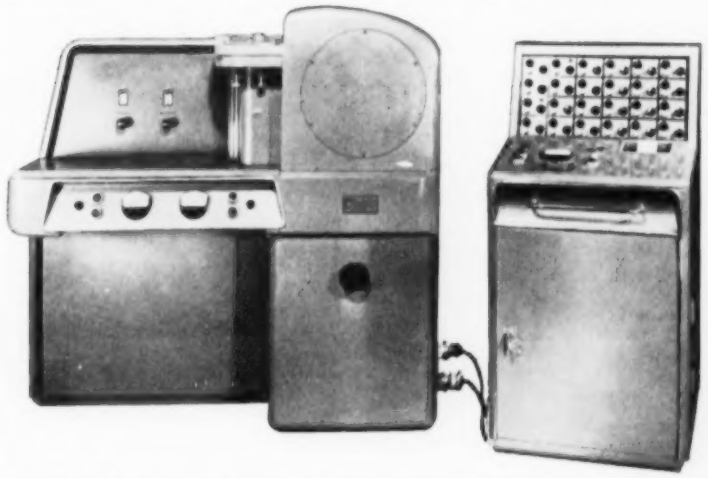

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*(Continued from page 1398)*

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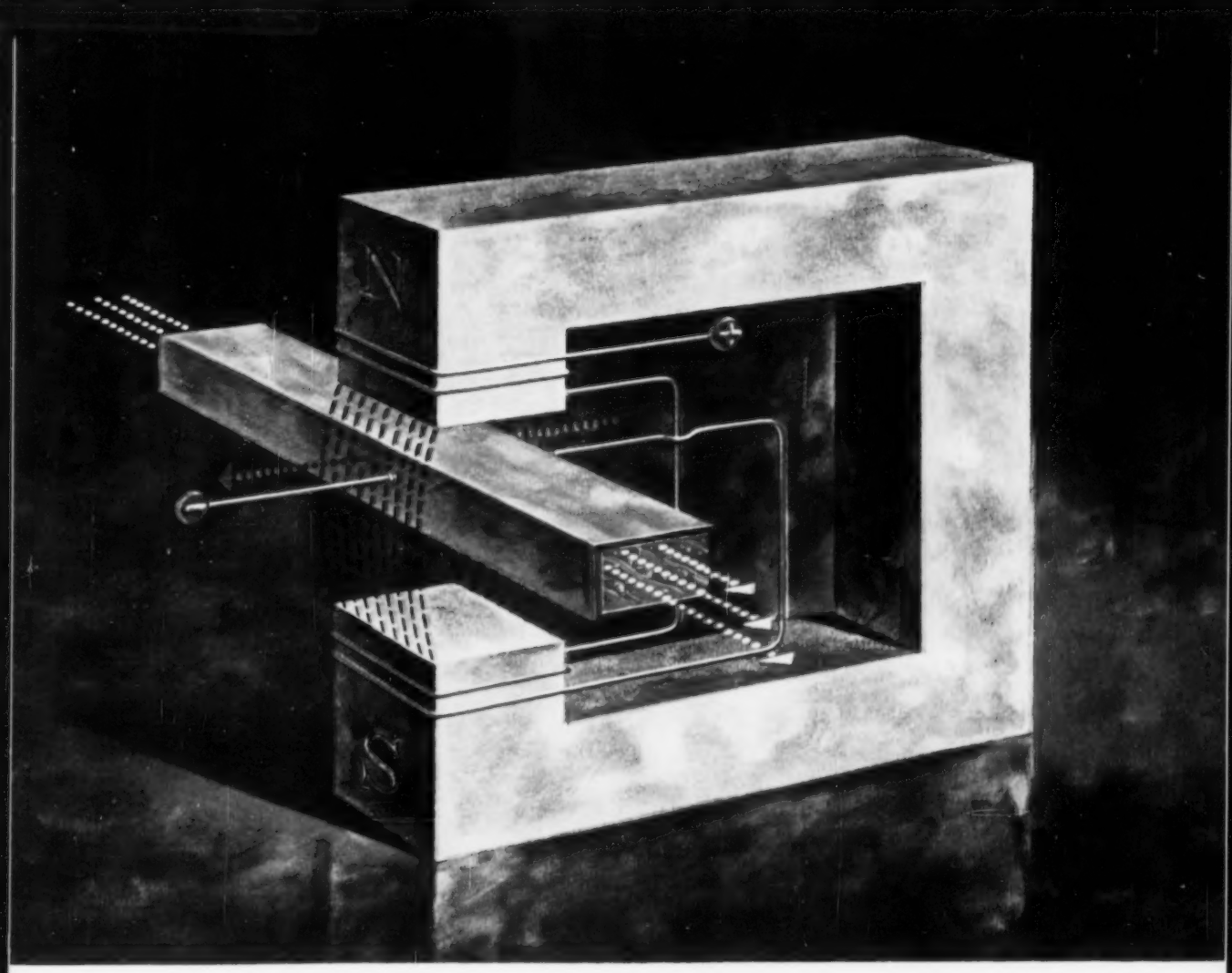

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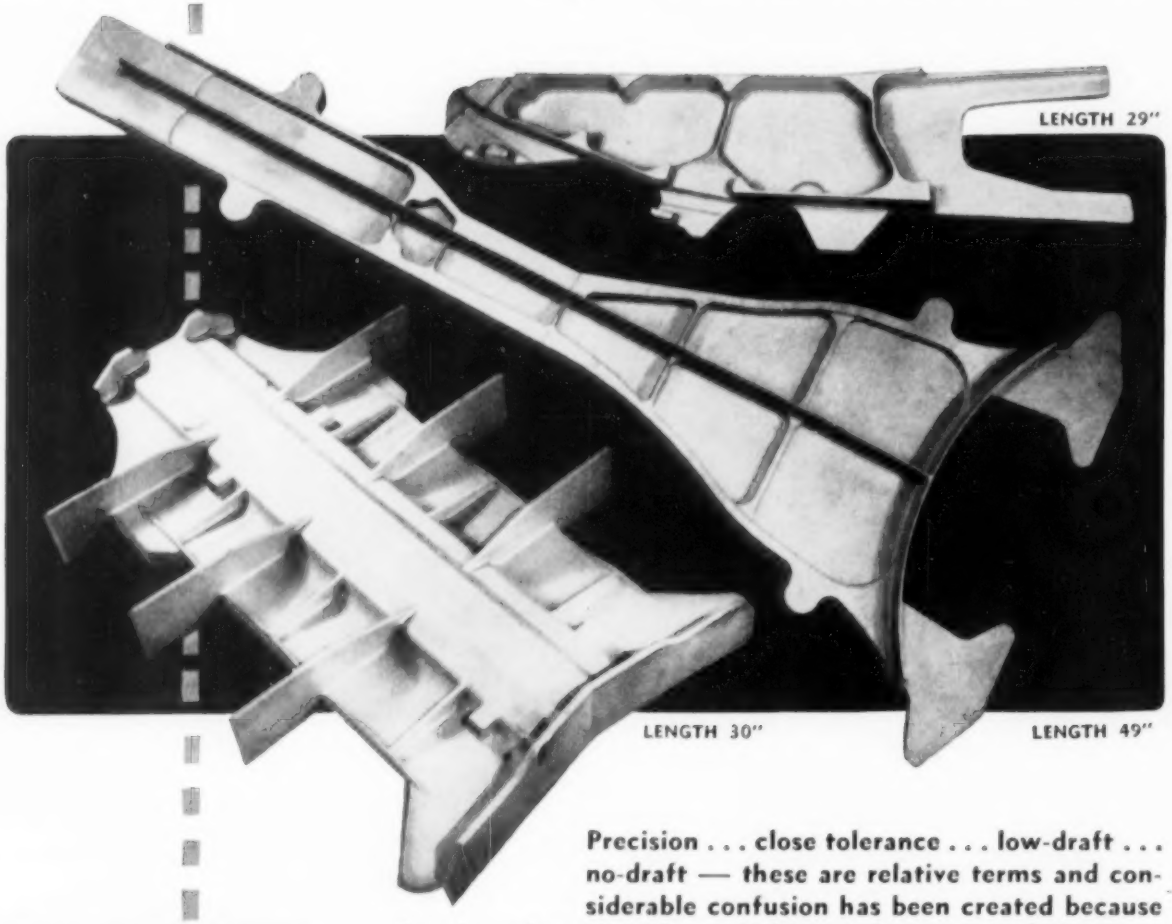

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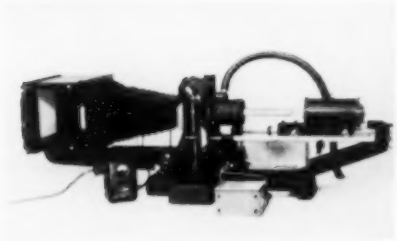

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**ASM Review of Metal Literature, 1956,** published by the *American Society for Metals*, 7301 Euclid Ave., Cleveland 3, Ohio. 858 pp., $15.00, 1957.—The thirteenth annual compilation of the world's metallurgical literature published monthly in "Metals Review." The abstracts are grouped into broad classes on the basis of process or property and are indexed by subjects and authors.

**Gmelin: Handbuch der Anorganischen Chemie,** System-No. 68, Platinum, eighth edition, *Verlag Chemie*, Weinheim, Germany. 638 pp., $90.00, 1957.—This volume deals with the arrangement of the material, the nomenclature, and formulae; provides summaries of the more important ligands, of the general properties of platinum complex compounds, and of the Russian literature concerning them; and gives a general treatment of the theoretical aspects of the field.

**Creep and Recovery,** *American Society for Metals*, 372 pp., $6.00, 1957.—An interesting guide for engineers and scientists who must deal precisely with metals is provided in this report of an important session at the 38th National Metal Congress which includes 14 outstanding papers.

**Recommended Practice for Repair Welding and Fabrication Welding of Steel Castings,** *Steel Founders' Society of America*, 52 pp., $0.50, 1957.—This handy reference represents the first revision of this manual since 1951 and contains a considerable amount of newly included material.

**Filler Metal Comparison Charts Available,** *American Welding Society*, 33 West 39th St., New York 18, N. Y. 24 pp., $2.00, 1957.—Sixty-one manufacturers cooperated by supplying data on their products. An alphabetical index lists the brand names and another index lists the full names and addresses of manufacturers.

*(Continued on page 1406)*

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## Books

*(Continued from page 1404)*

**Ductile Chromium,** *Technical & Engineering Book Information Service,* 7301 Euclid Ave., Cleveland 3, Ohio. 376 pp., $7.50, 1957.—Entirely new fields of usefulness for chromium and its alloys are forecast in this account of the significant work on the extraction, fabrication and properties of superior oxidation resistance and strength at elevated temperatures.

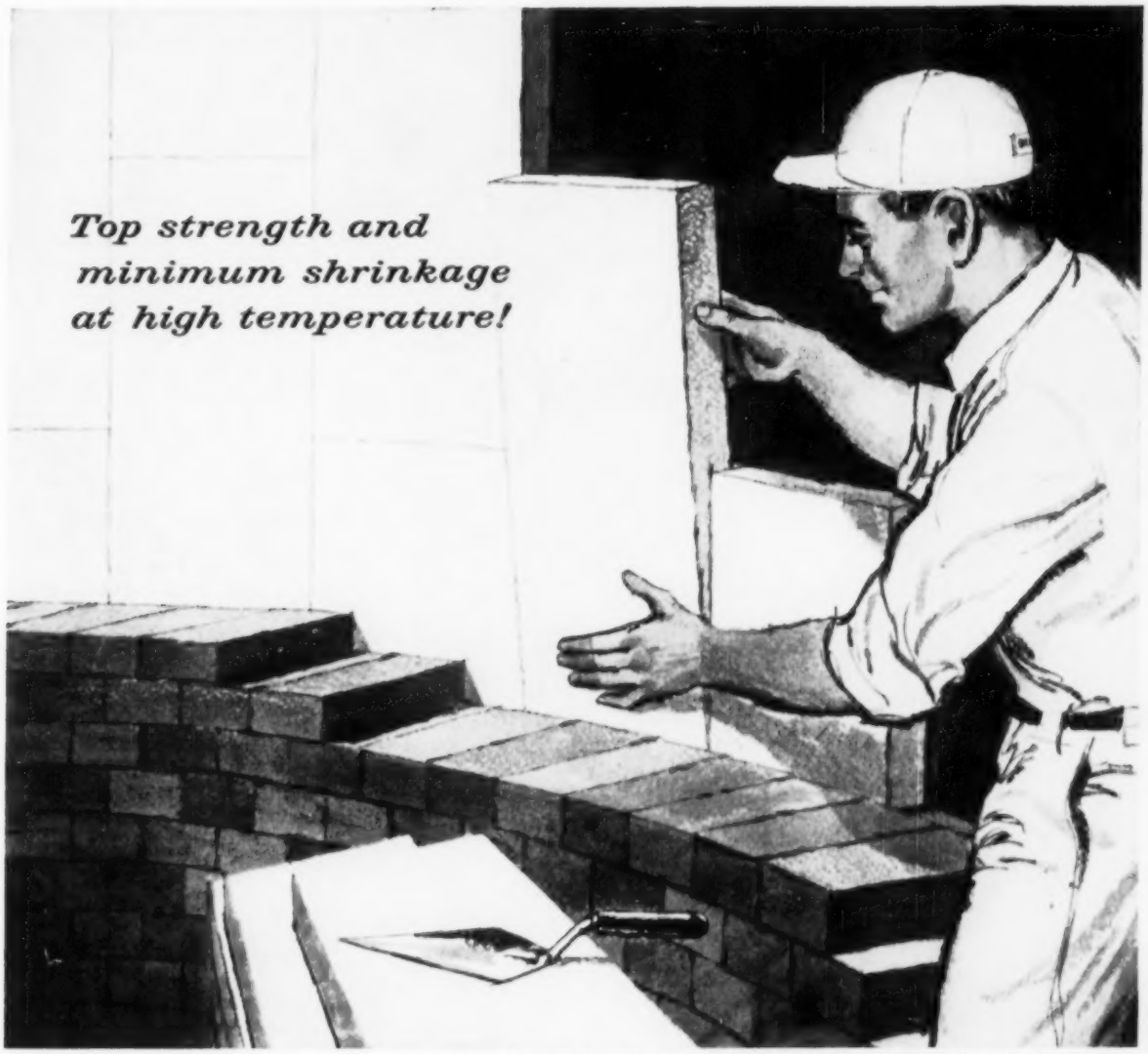
**Glossary of Terms in Nuclear Science and Technology,** *American Society of Mechanical Engineers,* 29 West 39th St., New York 18, N. Y. $5.00, 1957.—The book is designed to provide a common language among medical men, engineers, chemists, physicists, biologists and others working with the atom. It includes three categories of terms. 1) those invented expressly for the field of nuclear energy; 2) these borrowed from other fields and employed here with different meanings; 3) and those used elsewhere, but which may be unfamiliar to nuclear workers. Definitions, tables, charts and formulae considered useful are included in the glossary.

**Charting Steel's Progress,** *American Iron & Steel Institute,* 150 E. Forty-second St., New York, N. Y. 72 pp., free of charge, 1957.—Designed for the person who can see relationships more readily when statistics are presented in chart form rather than in figures, the booklet is conveniently classified into six sections. They are: 1) steelmaking raw materials, their sources and use; 2) steelmaking capacity, its location and growth; 3) expanding steel production; 4) distribution of steel products; 5) wages, hours and working conditions in the steel industry, and 6) the steel industry's financial affairs.

**The Making, Shaping, and Treating of Steel,** *United States Steel Corp.,* Office Service-Stores, 525 William Penn Place, Pittsburgh 30, Pa. 932 pp., $7.50, 1957.—Completely revised since its sixth edition was issued in 1951, the volume offers users and makers of steel a comprehensive summary of present-day theory and practice covering all phases of iron and steel production from raw materials to finished products.

**Corrosion: A Compilation,** by Mars G. Fontana, *Hollenback Press,* 2086 Elgin Rd., Columbus 21, Ohio. 240 pp., $5.95, 1957.—A compilation of a collection of columns on corrosion written over the past ten years for industrial and engineering chemistry. The articles are grouped into seven chapters (1) Nature and Extent, (2) Eight Forms of Corrosion, (3) Eight Methods of Combatting Corrosion, (4) Corrosion Testing and Evaluation, (5) Materials, (6) Environments, and (7) High Temperature Oxidation.

*(Continued on page 1408)*

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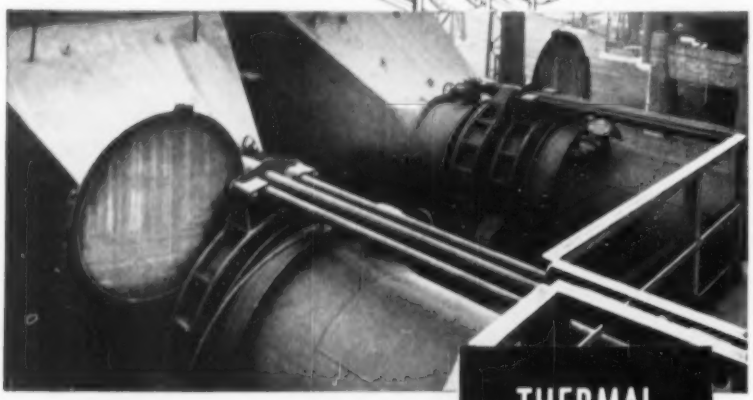

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## Books

*(Continued from page 1406)*

**A Handbook of Hard Metals,** by W. Dawihl, *Philosophical Library Inc.*, 15 E. 40th St., New York 16, N. Y. $10.00, 1957.—This book covers the important field of powder metallurgy and the production of carbides of metals with high melting points. The book contains a great deal of technical data, much in tabulated form. References to patentees are listed. A considerable amount of the data is presented in the form of charts and there are also a number of micrographs. •

**Magnesium Casting Technology,** by A. W. Brace and F. A. Allen, *Reinhold Publishing Corp.*, 430 Park Ave., New York 22, N. Y. $4.95, 1957.—The book describes an attempt which has been made to present objectively both British and American practice against a background of the more basic chemical and physical properties of the metal. •

**Neutron and Gamma Irradiation Facilities,** *Superintendent of Documents,* U. S. G. P. O. Washington, 25, D. C. 79 pp., $0.60, 1957.—The book describes the 40 irradiation facilities either operating now or expected to go into operation soon. Twenty-six are nuclear reactors; 14 are gammaray facilities equipped with sources of 3 kilocuries or more. The book explains services each facility provides and tells how to obtain them.

**Welding Handbook,** *American Welding Society,* 33 W. 39th St., New York 18, N. Y. over 560 pp., $9.00, 1957.—The fourth edition is claimed to be the most comprehensive work on welding ever published by the American Welding Society. Now available is Section 1.

**Corporate Secretary's Manual and Guide,** revised edition, *The Parker Publishing Co. Inc.*, Englewood Cliffs, N. J., 1600 pp., $12.50, 1957.—The manual outlines the duties of all corporate officers and provides for corporate secretary with a convenient checklist of the things that must be done for the efficient and legally sound handling of corporate affairs. It shows how to prepare and conduct corporate meetings; explains proper parliamentary procedure; gives assistance on stocks, dividends, taxes, borrowing and thousands of other matters with which the corporate officer must deal.

**Professional Engineers' Income and Salary Survey,** by the *National Society of Professional Engineers,* 2029 K St. N. W., Washingon 6, D. C., $1.00, 1957.—The survey, third in a series started by the National Society in 1952, is based on an analysis of 17,000 questionnaires returned from registered professional engineers in all the technical branches. The survey shows an increase of 21

*(Continued on page 1410)*

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## Books

*(Continued from page 1408)*

pet in the median earnings of engineers during 1952-1956, as indicated on the questionnaires returned, and gives other valuable information.

**Supplement to Encyclopedia of American Associations,** published by the *Gale Research Co.*, 1116 Book Tower, Detroit 26, Mich. $15.00, 1957. —Nine hundred national associations, societies, organizations, and labor unions are listed in the supplement. Each listing includes the national headquarters, executive secretary, number of members, founding date, and a brief description of the activities and purpose.

**Instructional Film Research Reports** volume II, published by the *Office of Technical Services*, U. S. Dept. of Commerce, Washington 25, D. C., 1033 pp. $6.00, 1957.—Volume I of this series, PB111000 **Instructional Film Research 1918-1950,** 185 pp., also is available from OTS at $2.50 a copy.

## News of EDUCATION

► Allegheny Ludlum Steel Corp. has made a grant to Rensselaer Polytechnic Institute toward the salary of a professor to lead study and research in the general area of the melting and solidification of metals. This year's grant of $5000 will be applied to the services of Wylie J. Childs, who has been appointed the Visiting Professor on the departmental staff. Dr. Childs, who has been associated with Lafayette College, will devote his major effort toward building up laboratory research and teaching in the general field of melting and solidification of metals.

Allegheny Ludlum has been interested for some time in problems of melting and casting metals in the education of engineers especially trained in these sciences. The corporation is currently carrying on vacuum melting and consumable electrode melting of super-alloys on a commercial scale, particularly at the Watervliet, N. Y., plant.

► Establishment of 268 four-year engineering scholarships at 48 colleges, technological institutes, and universities has been announced by Union Carbide Corp. This brings the total of Union Carbide undergraduate scholarships to 660 at 95 Liberal Arts and Engineering colleges and universities.

The new scholarships provide full tuition for four years of undergraduate study and allowances for necessary fees, as well as an annual grant to the college. The scholarships, which will go into effect this Fall, will be awarded and administered

*(Continued on page 1414)*

*You'll want these books for they cover virtually every aspect of nuclear energy*

# *ADVANCES IN NUCLEAR ENGINEERING

The 138 papers and discussions in this two-volume reference are from the 2nd Nuclear Engineering and Science Conference. They deal with the complete fuel cycle from the availability of natural resources to the radioactive recycle and waste disposal. They cover reactor plant design in all its detail. They discuss the metallurgical processing of materials used in reactor applications. They deal with problems of corrosion and include significant information on the radiation responses of important reactor materials. Additionally, these volumes contain several hundred references, an author index and a comprehensive subject index which gives you quick access to every subject covered as well as to related material.

PARTIAL CONTENTS: Fuel Manufacture, Production, and Recovery. Fuel Cycle Interrelationships. Spent Fuel Processing: Aqueous and Non-aqueous. Economics of Nuclear Fuels. Plant Containment Concepts and Design. Plant Components. Waste Disposal. Protection of Water Supplies. Shielding-Structural Protection and Control of Fission Products. New Limits and Codes for Radiation Protection. Merchant Ship Safety. Radiation Processing. Reactor Design. Reactor Core Design. Educational Use of Reactors. Uranium Metallurgy and Radiation Effects. Metallurgy of Reactor Materials. Metallurgy of Uranium-Zirconium and Uranium Niobium Alloys. Natural Resources. Reactor Plant Instrumentation. Reactor Control and Simulators. Reactor Instrumentation Development. Primary Coolant System. Heat Transfer and Heat Evolution. Problems Related to Heat Transfer. Standardization in the Nuclear Field.

**Edited by John R. Dunning and Bruce R. Prentice**

**Vol. I, 523 pages. 306 illustrations Vol. II, 581 pages. 600 illustrations 8½" x 11" $35.00**

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## 1957 NUCLEAR CONGRESS

which featured the 2nd Nuclear and 5th Hot Laboratories Conferences was sponsored by the following organizations, with the Engineers' Joint Council coordinating their efforts.

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# *HOT LABORATORY OPERATION AND EQUIPMENT

This book contains the most complete information currently available on the equipment and tools for handling radioactive materials. Included are the sixty-odd papers presented at the 5th Hot Laboratories and Equipment Conference plus a considerable amount of additional material added by the authors after presentation of the papers. Topics covered range from a discussion of the principal engineering design features of hot laboratories to the key specifications of equipment for hot chemical, physical, mechanical and metallurgical operations, operational and maintenance problems; those encountered in hot cell installations and in specialized operations such as, the operation of decontamination facilities and of in-reactor pump loops, the removal and dismemberment of radioactive in-pile units and a shielding pot that can be used as either a horizontal or vertical carrier. A cross-referenced subject index is also included.

**Edited by Frank Ring, Jr. and P. J. Glasson**

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The contributions in this volume are concerned with waste disposal and radiation hazards, dissolution of solid fuel elements, the chemistry and engineering of the aqueous processing of fuel and blanket materials, pyrochemical methods, methods involving fluoride volatility differences, experimental low-power assemblies, reactor physics, instrumentation and control.

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These two volumes were edited by D. J. Hughes, Stuart McLain and Clark Williams. The 87 contributions in them were selected from the papers presented at the 1st Nuclear Engineering and Science Conference held in Cleveland, December 1955.

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## Education

*(Continued from page 1410)*

by the individual colleges concerned. The present announcement covers plans for an expansion of the program started in 1952. The previous program, which provided technical senior year scholarships, has been discontinued.

The Union Carbide Engineering Scholarships were established to enable more students who desire an engineering career to obtain a college education, as well as to provide greater financial assistance to engineering colleges and universities. Receipt of a scholarship does not involve future employment commitments by either the student or the Corporation.

► The International Nickel Co. Inc. has renewed its scholarship at the Colorado School of Mines which it established last year. The scholarship pays all tuition and fees and provides the recipient with $300 annually for four years. Frederick Schwarz has been awarded the scholarship for the current year. Concerned with minerals as it is, the company requested that the scholarships be restricted to students who are working in an option dealing with ores. Otherwise, no limitations were placed on the scholarship.

The company also made a contribution to the School's development program and it will probably be used immediately in the faculty development phase of the Horizon Plan.

► The Frontier Refining Co. has contributed 50 books to the Colorado School of Mines Library as a memorial to the late Harold D. Roberts. Mr. Roberts, who was awarded an honorary doctor of engineering degree from Colorado School of Mines in 1946, served Frontier as legal consultant. M. H. Robineau, president of Frontier, presented a check for $500 to the Colorado School of Mines Foundation Inc. with the request that the gift be used through the School's development program to provide Harold D. Roberts Memorial books for the library. Technical books dealing with various phases of the petroleum industry have been added to the Mine's library in keeping with Frontier's request. The collection is now available for use.

► Plans to offer courses in nuclear engineering at Carnegie Institute of Technology were announced in August by John C. Warner, Carnegie's president. The courses at the College of Engineering and Science will lead to a master's degree in nuclear engineering for students who have done undergraduate work in the closely related fields of mechanical, chemical or metallurgical engineering; physics, mathematics, or chemistry. Nuclear engineering will be a cross-department program, using new courses pin-pointing nuclear topics and a broad sweep of established courses in the above mentioned fields. Carnegie's course in nuclear engineering may begin as early as September 1958, so that students now taking undergraduate work may enter the program after graduation.

► ORSORT, a co-operative program which Carnegie Institute is conducting for the Atomic Energy Commission, is offering a high level course in nuclear subjects. The student, and industrial or government employe sponsored by his employer, takes six months pre-ORSORT study in physics, mathematics, chemistry, and engineering on a university campus, then goes to Oak Ridge, Tenn., to complete another six months of classified concentrated work in reactor mechanisms and technology.

The first of the ORSORT classes at Carnegie completed its work on July 26 and began its sessions at Oak Ridge on September 9. Its members received college credit for their work and several will be awarded master's degrees.

Group II of the pre-ORSORT students commenced on July 29 and will finish next January 30. Subsequent classes will begin at Carnegie Tech in February and September, 1958.

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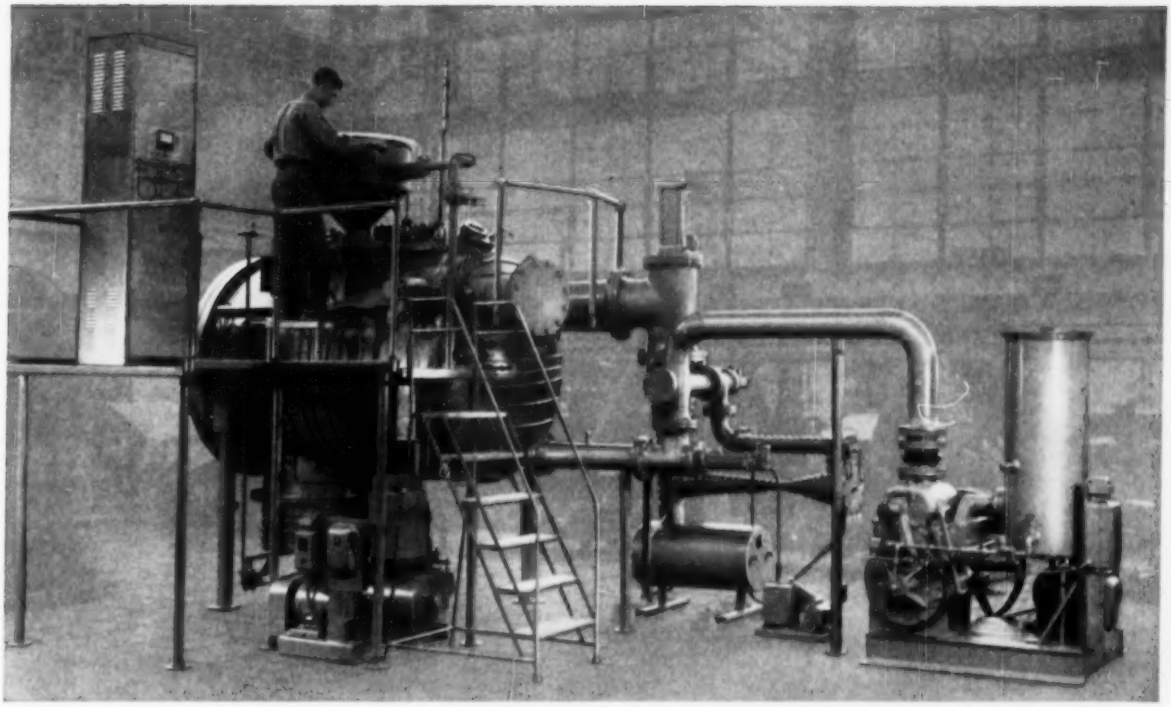

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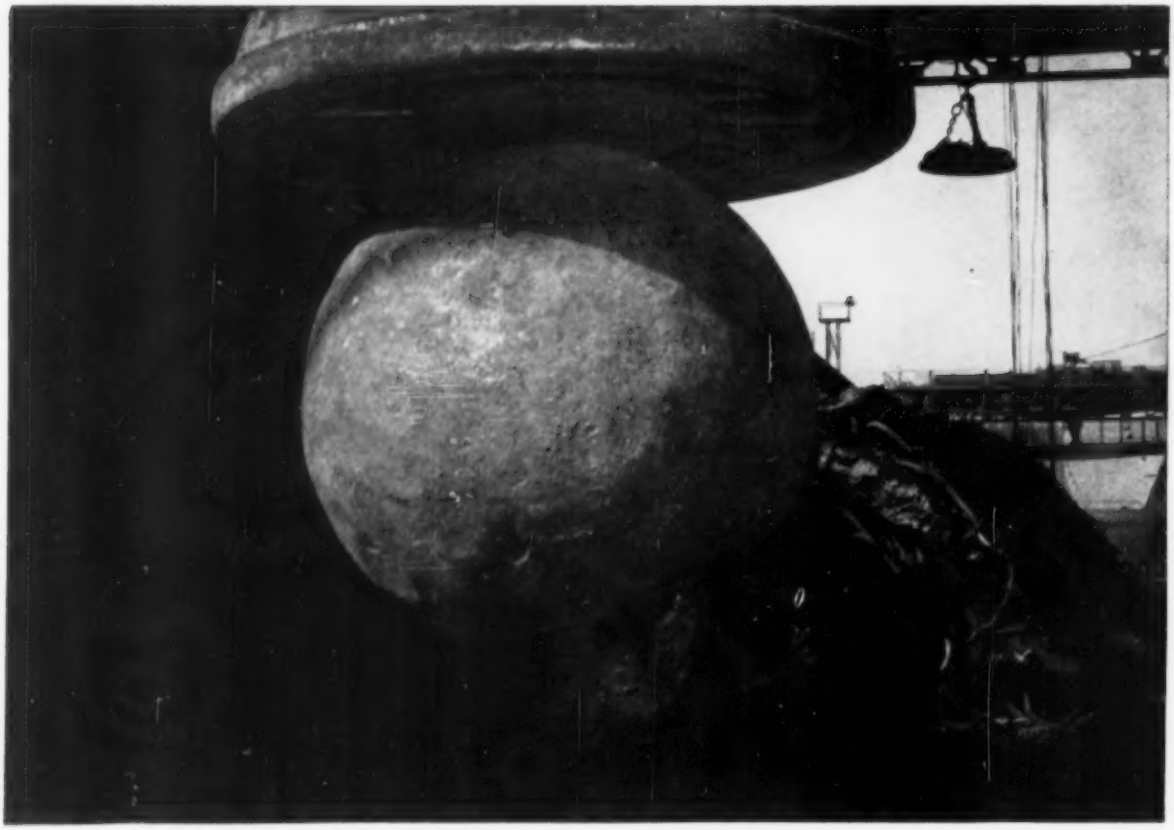

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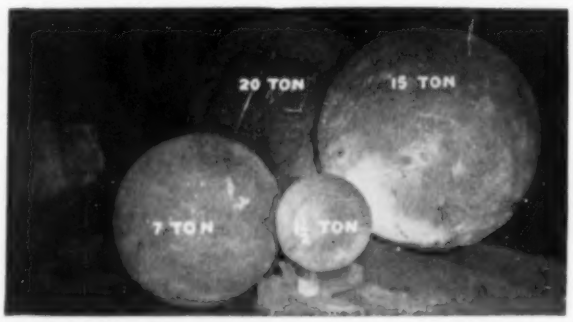


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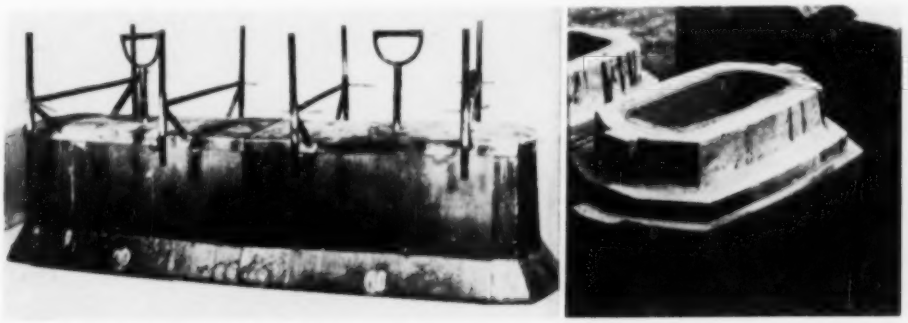
INCO THE INTERNATIONAL NICKEL COMPANY, INC. 67 Wall Street New York 5, N.Y.

## Self-Hardening Hot-Tops, a Swedish Development

At the Eastern Section of NOHC, R. R. Fayles of Lukens Steel Co. presented a paper on Steel Plants in Europe. Among other developments, he told of seeing at Avesta and other steel works in Sweden a new hot top made in the pit from sand or crushed slag and wetted with sodium silicate. The mixture is formed in the mold by use of a simple collapsible tool—called *Umbrella*. The mass is hardened with $CO_2$, and the umbrella is collapsed and lifted out. The top can be made for almost any mold size in less than 8 min. It it is now being introduced in the U. S. under the name of *Tiger-Top*.



At left, collapsible umbrella for large slab ingot mold; at right, hot-top made by new technique.

## Large New H-Iron Plant

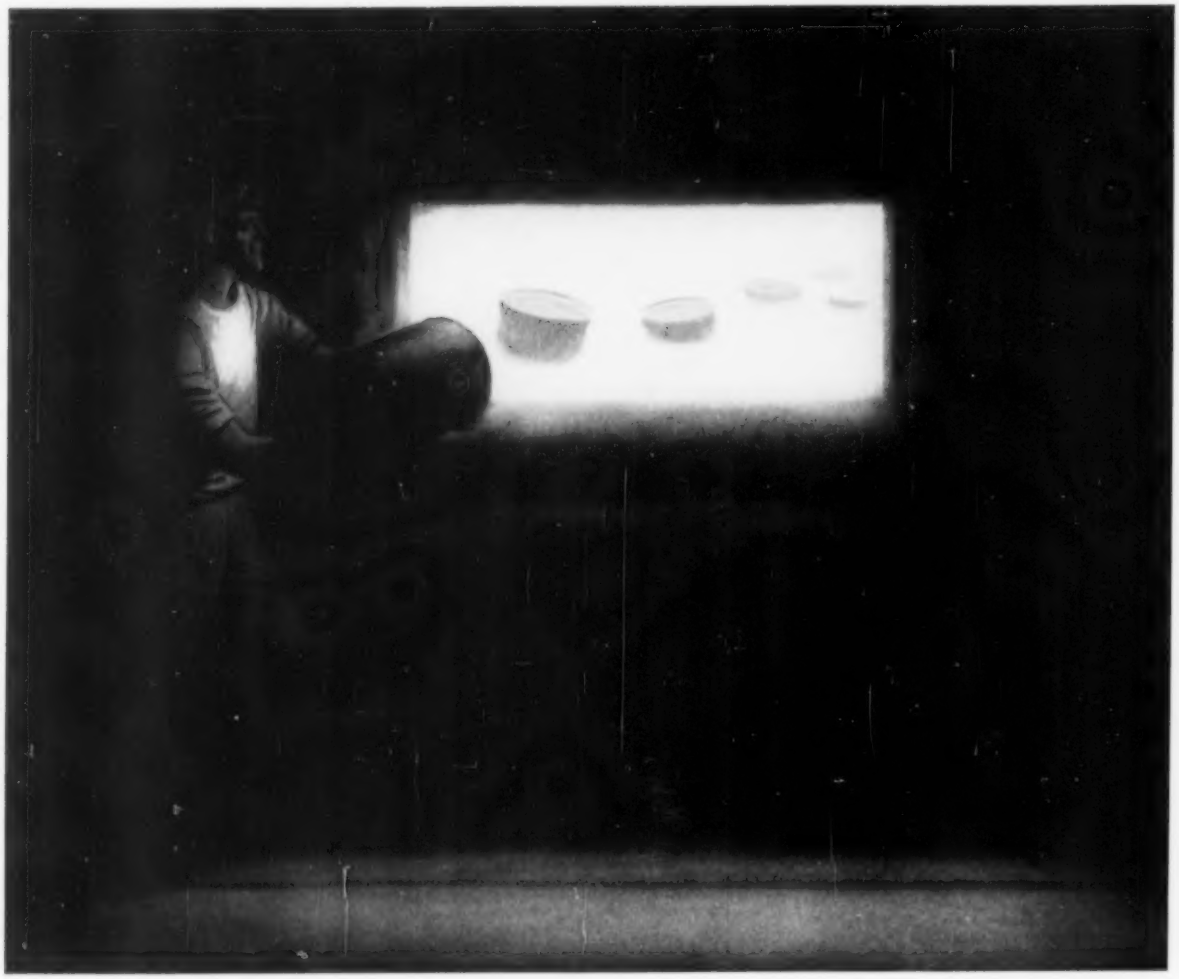
Construction of a $3.5 million plant for the production of 50 tpd of iron powder will be undertaken shortly by Alan Wood Steel Co. at Ivy Rock, Pa. The plant, expected to supply some 25 pct of the U. S. market for iron powder estimated at 32,000 tons annually, is to make use of the H-Iron process developed by Hydrocarbon Research. The plant's hydrogen requirements will be met from the firm's own coke-oven gas, while ore—in the form of high-grade concentrate—will be supplied by the Scrub Oak mine at Dover, N. J.

## New Krupp-Renn Plant at Essen, Germany

Three of the six kilns of one of the world's largest Krupp-Renn plants are reported to be in operation at Essen, Germany. Financed by eight Ruhr steel firms and the European Coal and Steel Community, the plant upon completion will supply 400,000 tons of sponge—90 to 93 pct Fe—to relieve tight scrap supplies. The kilns—110 m long and 4.6 M in diam—are being fed on imported low-phosphorus ores.

## New Metallurgical Laboratory

The Caterpillar Tractor Co. of Peoria, Ill., opened its new Production Metallurgical and Materials Testing Laboratory last month. Designed both as a quality control and a process development laboratory, the new facility can run metallographic, spectrographic, chemical, and ultrasonic tests on all materials going into Caterpillar products. Also unveiled was the first commercially successful application of boron-bearing cast carbon steel made by the acid open-hearth process. Designed for use in a tractor sprocket, the new alloy was developed in conjunction with Harrison Steel Castings Co.



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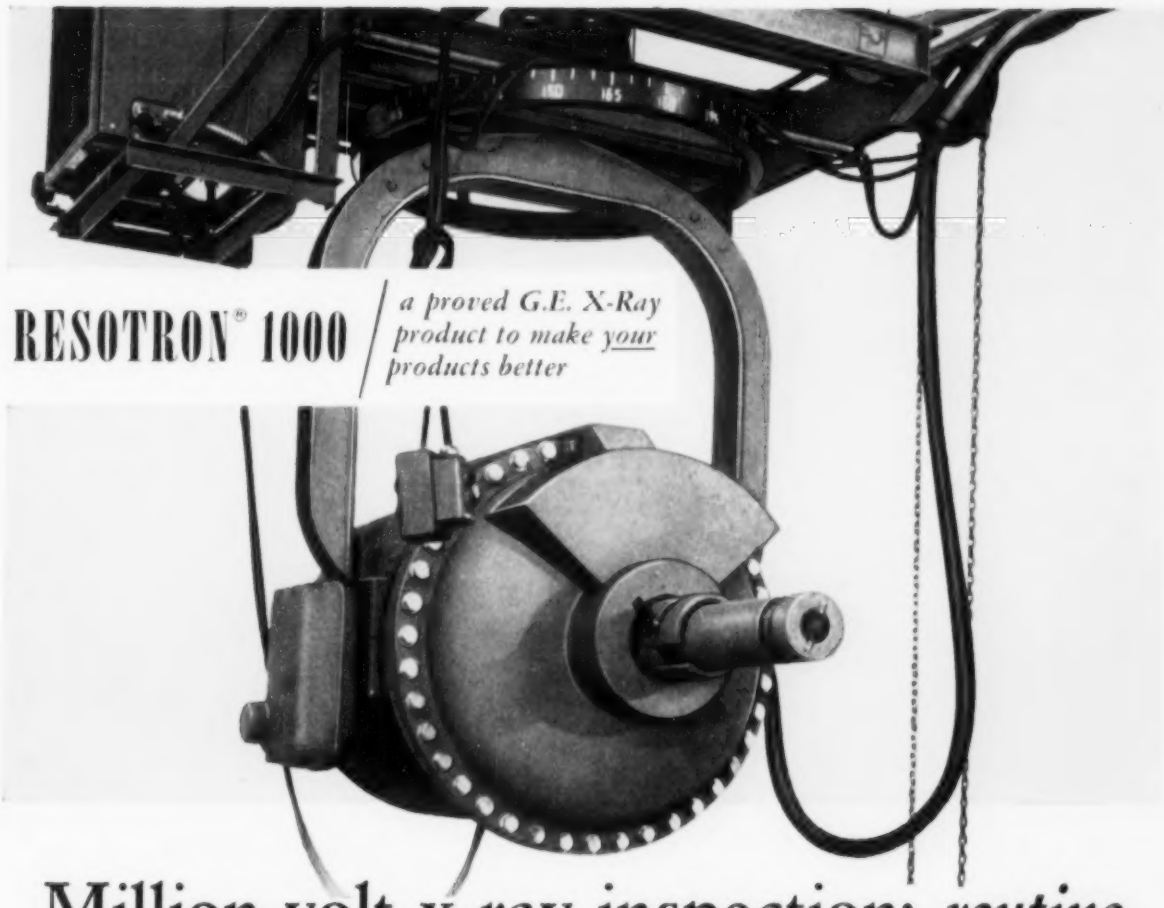

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EDITORIAL

# Institute of Metals Division

# Presents Purposes and Programs

UNDER the Bylaws of the Institute of Metals Division, as constituted under The Metallurgical Society, one of the objectives of the Division is to provide—

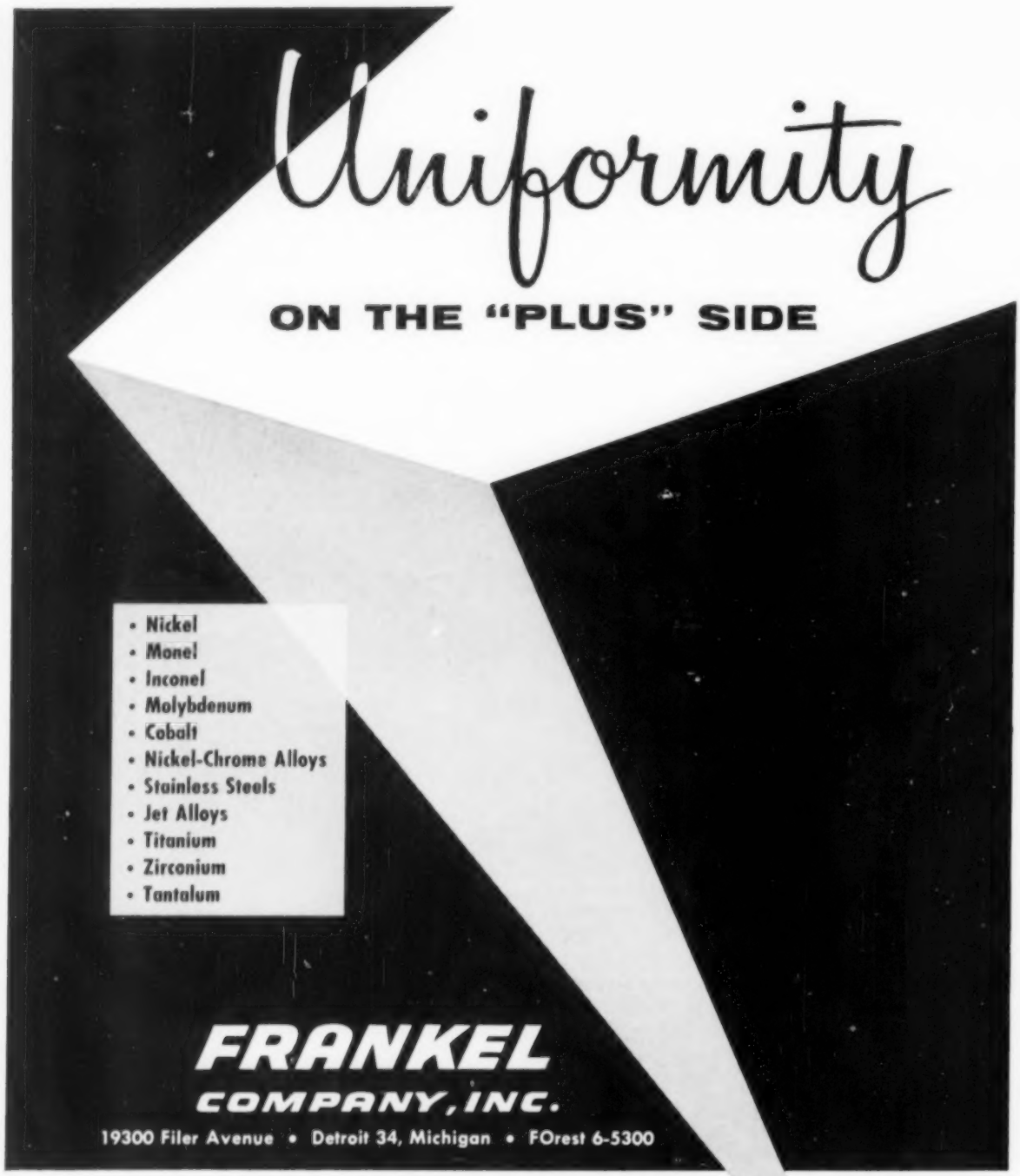
> "a medium for communication and cooperation among those interested in any phase of theoretical and applied physical metallurgy, including those advancing, practicing, learning, or otherwise primarily concerned with the science, engineering, economy, or technology of the metals industry in this field (producer and consumer). Physical metallurgy encompasses particularly the understanding and knowledge of metal behavior, the manufacturing practice for fabricating metals, the development of metals and their alloys, and the nature, structure, heat treatment, properties and utilization of metals."

It is thus the responsibility of the IMD to maintain timely programs in significant critical areas of theoretical and applied physical metallurgy. In the past we have depended largely upon our publications to develop our programs, but recently these have been decentralized. It becomes essential to form additional technical committees in those critical areas where they do not now exist. The purpose of technical committees is to examine the progress of science and technology in their fields and arrange and schedule programs at timely intervals when progress and interest dictate. Such committees are already operating effectively in such fields as nuclear metallurgy, titanium, high-temperature metallurgy, and powder metallurgy.

New committees were authorized by the Executive Committee and are being activated in the following areas: Electrical and Magnetic Metals, Shaping and Forming, Corrosion Resisting Metals, Physical Metallurgy, Heat Treating, Structural Materials, Joining, Ferrous Metallurgy, Non-Ferrous Metallurgy, Melting and Casting, Surface Treatment, Refractory Metals.

It is hoped that these committees will better serve the membership by developing more extensive activities and participation throughout the Division. It is our intent that at least one committee will interest each member of the Division. If you would like to participate in these new activities, please contact R. W. Shearman, our Secretary; R. L. Smith, our Program Chairman; the Chairman of the appropriate Technical Committee, or write to me or to W. J. Harris, Jr. If you think that other new committees are appropriate, please contact J. Harry Jackson, Chairman of the Scope Committee.

*W. R. Hibbard, Jr.*

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No wonder more and more buyers of secondary special alloys are turning to Frankel.

# GERMANY'S RUHR

THE "Ruhr"—an area of some 2000 sq miles extending along the Ruhr river eastward from the Rhine for 40 miles to Dortmund—shelters Europe's tightest concentration of industry. Some 10 pct of Western Germany's labor force are employed here; it has nearly a third of the Country's industrial plants and produces some 90 pct of its hard coal.

Prior to the 17th Century, the Siegerland, a neighboring area to the south, was the center of the iron smelting industry of central Europe. It was only in the 19th Century that iron making commenced in the Ruhr with the discovery of local ore deposits, but this ore output reached its peak in 1860 and then dropped off to negligible quantities. Iron deposits still exist in some neighboring regions, but it was coal that made the Ruhr, and since 1870 the Ruhr mills consumed more imported than domestic iron ores.

Again alive with a renewed fervor of production pulsating in its veins, today the Ruhr's ferrous and nonferrous industry's expanding output is becoming more and more dependent upon imports of coking grades of coal. Ruhr coal mines, brought into full production in the middle of the last century, have been heavily taxed to sustain German power in three major wars, and today, in spite of considerable investment, they are unable to match their production of metallurgical grades of coal to the present mounting peace-time needs. The result: a search for new metallurgical techniques, some of which are outlined in this issue on Germany's Ruhr.

by F. Weston Starratt

# THE AUGUST THYSSEN HÜTTE

*American equipment and technical know-how help rebuild important German steel mill heavily damaged by wartime bombings and largely dismantled during the early post-war years. Today, with almost completely new equipment, including a 66-in. continuous wide-strip mill, and its crude steel capacity approaching the pre-war figure of 2.4 million tons, the August Thyssen Hutte stands as a monument to German-American technical cooperation.*

FOUNDED in 1890 in a suberb of Duisburg, Germany, the August Thyssen Hutte—ATH—was built directly on the Rhine River with its own harbor facilities, providing cheap and easy transport, and giving the mill access to the Dutch and Belgian sea ports as well as the west German canal system. Of equal importance are mines producing good quality metallurgical coals located adjacent to the steel plant. With such an ideal location, the August Thyssen Hutte prospered greatly, and by the outbreak of World War II it had a capacity of 2.4 million metric tons of crude steel. Its rolling program consisted of rails, structurals, merchant bars, wide-flanged beams, and special quality sheet.

## January 1945—Production stopped

Seriously affected by Allied bombings, the Thyssen Hutte discontinued production in January 1945. During the ensuing months considerable progress was made in the clearing of rubble and in the repair of equipment, but permission for resumption of production was not granted by Allied occupation authorities. The plant lay almost idle for over two years.

## October 1947—Plant scheduled for complete dismantling

In October 1947 all equipment for the production of iron and steel, together with auxilliary installations, was earmarked for dismantling. Of the 4 million tons of crude steel capacity scheduled to be removed from the Ruhr by the dismantling program, some 60 pct fell on the Thyssen plant. Dismantling started in September 1948; after a temporary lull it was continued with ever increasing intensity from May 1949 until finally stopped by the Petersberg Agreement with the Allied occupational authorities in November 1949.

By that time ATH had been reduced to 20 pct of its prewar capacity. Of the approximately 117,000 tons of equipment removed, 70 pct was scrapped and only a minor part of the remaining 30 pct was usefully employed elsewhere. Seven out of the eight blast furnaces had been retained, but all of these had to be repaired and relined. The furnaces and equipment in three of the four steelmaking plants had been completely dismantled or scrapped, and in the other steelmaking plant only a few furnaces had been spared. The rolling mills had suffered most: all three blooming mills, six finishing mills, as well as the four-stand sheet rolling mill had been lost. Only two finishing mills, which included a five-stand mill for semis, rails, and structurals were retained.

## The deconcentration program—detachment from coal

Almost equally serious for the August Thyssen Hutte was the Allied deconcentration program, designed to break-up excessive concentration of German industrial power. While the need for such an operation in relation to various horizontal groupings was recognized, the program for the disengagement of steel mills from coal mines and coking plants was subject to considerable controversy.

The Thyssen Hutte, the main unit of the former Vereinigte Stahlwerke, was not only split from the other steel mills of the organization, but also it was separated from its raw material basis—coal.

As has been pointed out, ATH was located directly on coal deposits so as to provide the most economic utilization of this vital raw material, but during 1947 separate firms were set up to mine and carbonize this coal. Such an awkward situation was only partially mitigated through long-term supply contracts drawn up with the new coal firms.

## November 1949—Limited scale production permitted

Things began to change for the August Thyssen Hutte—and for the Ruhr steel industry in general—in November 1949 when agreement between the newly formed Federal German Republic and the Allied High Commission put a final stop to dismantling and permitted resumption of limited production at the Thyssen Hutte. The agreement allowed the production of 600,000 tons of pig iron per year from three blast furnaces and 117,000 tons of crude steel per year from two open-hearth furnaces. Bessemer steel and rolled products could not be produced.

With the plant in a general state of disrepair it took some time to put even these facilities into

operation. But in March 1952 the first phase of reconstruction was completed with three blast furnaces and two open hearth furnaces again in operation.

## 1952, Long-term reconstruction program begun

With hope revived, work turned toward planning a rebuilt August Thyssen Hutte equal in capacity to that of the old plant.

It can be argued that the rebuilding of ATH provided an opportunity seldom enjoyed by the older steel mills. In its reconstruction installation could be made of the latest types and designs of high-efficiency steelmaking equipment. This provided the chance for a complete rationalization of the rolling program to take advantage of new high-speed rolling mills and changes in the market for steel products. In Germany, as in other industrial countries, steel demand had shown considerably greater emphasis on flat products, particularly of the thinner grades. Thus, in rebuilding, ATH's goals were not merely the prewar crude steel capacity, but an efficient up-to-date steel mill with a rolling program designed to meet the needs of the German market.

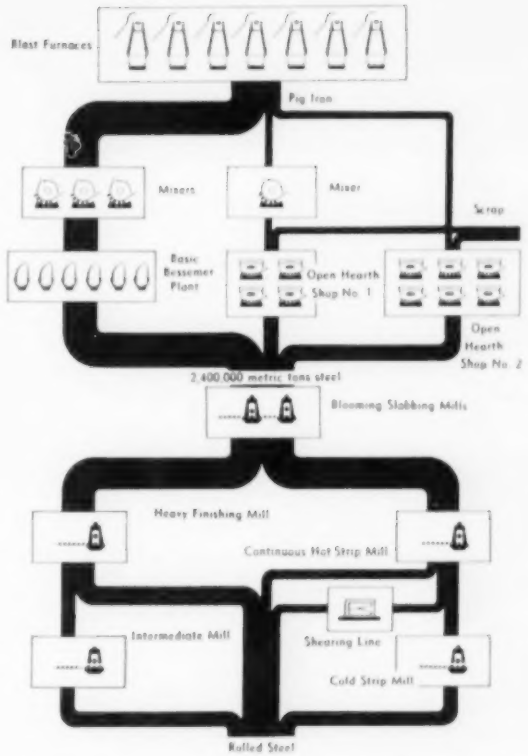
## A technical assistance agreement with Armco

Fully realizing that, in many ways, the German steel industry had fallen years behind technologically, ATH took active means to learn of the latest American steelmaking techniques. The company's program depended to a great extent on the purchase of American-made equipment and cooperative technical programs with U. S. steelmakers. Thus, ATH signed an agreement with Armco whereby Armco engineers would serve in a consulting capacity in the design, installation, and early operation of the new mills. ATH employees were also sent on extensive training programs to the works of Armco to permit them to learn on-the-job the operation of the latest type mills and furnaces. ATH also has close connections with U. S. Steel Corp. with whom they are exchanging information.

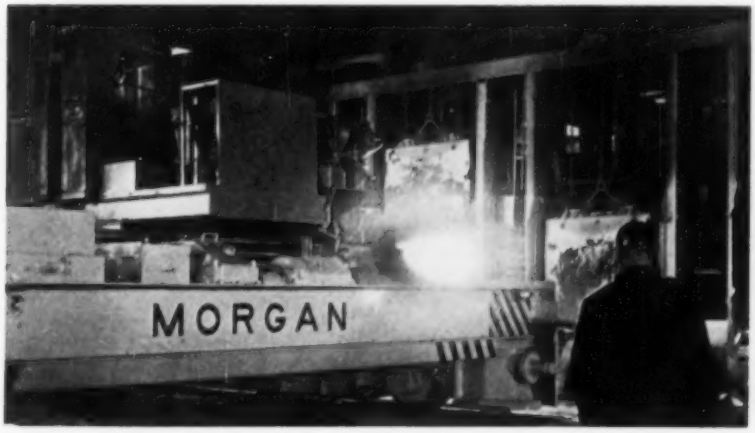
## Rebuilding features wide-strip mill

In the new ATH, the main emphasis has been the continuous hot wide-strip mill, with steel furnaces geared to supplying it with sufficient steel and continuous cold strip rolling and sheet handling equipment designed to further process its output. Nevertheless, production is not limited to flat products, and the new plant includes a heavy finishing mill—remaining from the old plant—and a medium finishing mill. One new blooming/slabbing mill rolls blooms for the latter two mills, and another new blooming/slabbing mill supplies slabs to the continuous hot-strip mill. ATH is, thus, in a position to supply its former line of rails, wide-flanged beams, structurals, and merchant bars, as well as the new field of production: hot and cold rolled coils and sheets.

In addition to the above, investment in new plant also included: a coke-oven plant with 345 ovens, seven rebuilt blast furnaces, six new 40-ton con-




**Flowsheet of rebuilt August Thyssen Hutte, with its prewar capacity of 2.4 million metric tons of crude steel, shows heavy emphasis on production of flat products.**




**Ten-ton Morgan machine charging 250-ton open hearth furnace built by Loftus Engineering Co. American charging technique is used because it provides "shortest charging time with a minimum expense for cranes".**

verters, four new 250-ton furnaces in the new open hearth plant No. 1, and six furnaces—four retained from the old plant—in open hearth plant No. 2.

## November 1957—Reconstruction program nears completion

Apart from a battery of coke ovens at present under construction, all of the facilities in the long range plan have been put into operation. Before the end of 1957 ATH will, thus, have regained its prewar crude steel capacity of 2.4 million metric tons. However, there has been greater emphasis on pig iron—partially because of the continuing scrap shortages—and the ATH is already producing some 40 pct more pig iron than during prewar days; its annual capacity is 2 million metric tons. Pig iron output is still insufficient when it is considered that one blast furnace will generally be down for relining; therefore, ATH has plans for an eighth furnace, completely new and on the scale of the large American blast furnaces. The furnace—to be completed in 1959—will be the largest in Germany, with a hearth diameter of 9 m and a daily production of 1500 metric tons of pig iron.

It can be assumed that there will be further additions to crude steel capacity, for with a strip mill of almost 2 million tons capacity and a medium and a heavy finishing mill with a combined capacity amounting to 1.2 million tons, a crude steel capacity of 2.4 million tons is hardly sufficient for economic rolling operations.

## American financial aid helped rebuild ATH

To carry through what amounted to an almost complete rebuilding of the steelmaking plants and rolling mills some $165 million was required. Initial financing was through grants and various forms of aid by the state government of Nord-Rhein Westfalen and by the Federal German Government, but during the last two fiscal years the firm itself has met a considerable amount of the capital expenditures by reinvesting its own income.

Much of the equipment and know-how for the new ATH was purchased in the U. S. Some of this was financed from the German side, but some of it also came from various American aid, including a $10 million Export-Import Bank loan made during 1956. Actually, the latter loan is being used largely for the purchase of additional equipment not included in the original plan: a Hallden flying shear for hot strip made by Hallden Machine Co., a third down-coiler for the hot strip mill built by E. W. Bliss Co., and an Armco-Sendzimir continuous galvanizing line made by Aetna Standard Engineering Co. with furnace equipment by Electric Furnace Co. This equipment will permit a larger and a more diversified flat product production program. A further step in this direction is a recent agreement with Armco for production by ATH of silicon steel and its rolling into grain-oriented transformer sheet in France.

## New ATH places emphasis on open hearth steels

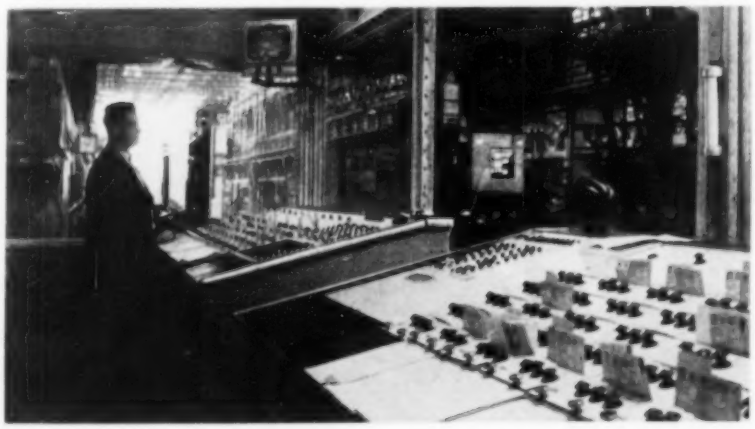
The increase in the proportion of flat products in the rolling program of ATH from 2.5 pct prewar to some 60 pct has been reflected in a shift in the types of steel produced. Thus, in the new plant greater capacity was scheduled for the open hearth side—45 pct of the total crude steel output compared with only about 25 pct in the prewar plant. While the capacity of the partially rebuilt open hearth shop No. 2 remains substantially as before—35,000 metric tons—the completely new open hearth shop No. 2 is being constructed with a monthly capacity of 55,000 metric tons and room for further expansion. Open hearth output is almost entirely for the wide-strip mill.

In the basic bessemer shop—rebuilt with six modern 40-ton converters to a monthly capacity of some 110,000 metric tons—emphasis has been given to oxygen-enriched blowing so as to produce steel of the quality and type required for rolling on the wide-strip mill. The basic bessemer plant produces exclusively rimming grades of steel, largely for the heavy and medium profile mills, but a substantial quantity is also for the wide-strip mill.

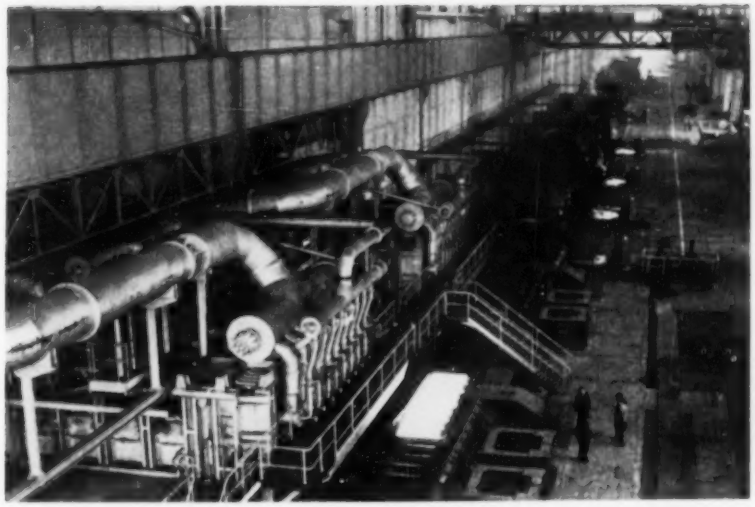
## New open hearth shop features Europe's largest furnaces

The completely new open hearth shop No. 1—now in full operation—has four 250-ton open hearth furnaces, two designed by Loftus Engineering Co. and two by DEMAG in conjunction with ATH engineers.

A careful study was made of the technique of open-hearth furnace charging, whether it be by the classical German technique with a scrap bin the length of the open hearth shop and a turning crane, or by the American method with charging buggies



Control pulpit for soaking pits features closed-circuit television close-up of both blooming/slabbing mills to provide for continuity of operation. Controls are largely Minneapolis-Honeywell built. Each ingot is accompanied by a tag bearing its analysis and heat number; this tag is placed in a pigeon-hole corresponding to the ingot's position in soaking-pit furnaces.



Two of the three slab heating furnaces built by Rust Furnace Co. supplying the 66-in. continuous hot-strip mill. Each furnace has an hourly heating capacity for 100 tons of slabs heated to 1280°C.

on rails in front of the furnace and a charging machine. Decision was for the American technique, because it provided the "shortest charging time with a minimum expense for cranes". Two 10-ton charging machines built by Morgan Engineering Co. have thus been installed. Further American practice can be found in the mechanization of the dolomite distribution in the furnace prior to charging; Blaw-Knox machines are being used for this purpose.

In order that production will not be unduly dependent upon a seemingly ever-tight scrap market, the furnace charge is made up of 40 pct liquid iron and 60 pct scrap—this by European practice is a very low scrap charge. A 1000-ton mixer has been installed for the liquid pig iron.

Each furnace has a hearth area of 90 sq m with a maximum depth of 420 mm; they are of basic construction with the exception of the main arch. Each open hearth has two air heating chambers with a capacity of 560 cu m of which 365 cu m is filled with checker bricks. The furnaces may be fired with coke-oven gas, mineral oil, or tar oil. Either oil is heated to 130°C prior to burning, and air for the burners is compressed to 7 atm and heated to some 250°C.

Each pouring is from 250 to 270 metric tons in one ladle. Top poured ingot molds are used with four molds placed on one car, and from 36 to 40 ingots are cast at one pouring. These ingots weigh from 7.5 to 14 metric tons. Stripping is done by two 40-ton stripper cranes, and the hot ingots are moved by rail to the soaking pits.

## Soaking pits fully mechanized

There are 32 large soaking pits at the new ATH, each with a capacity of 60 to 75 tons. From one air-conditioned control pulpit directions are given for the loading and removal of ingots. An identification card is recevied by air tube from the casting bay simultaneously with the ingot; this card subsequently follows the ingot throughout its entire rolling and processing. In the soaking-pit pulpit, the card is placed in the proper pigeon-hole, representing its position in the respective soaking pit. By means of a telewriter, the pulpit receives the analysis of the ingot from the laboratory, and this is inscribed on the identification card.

The soaking-pit pulpit has a large control panel —Minneapolis-Honeywell built—which, by means of colored lights, automatically shows when ingots have reached the proper temperature.

From these soaking pits, hot ingots are fed to either blooming/slabbing mill. In this transfer, the operator in the pulpit is aided by two television cameras placed some 100 yds away at the rolling mills. The operator can watch every movement of the ingot on his screen, and, at the same time, he can have the next ingot ready to be pulled from the oven. Thus, there is a continuity of operation.

## Two blooming/slabbing mills

The ATH has two blooming/slabbing mills with a combined rolling capacity of 330,000 metric tons per month. One is largely employed to roll blooms for the profile and semis mills, while the second rolls slabs for the hot strip mill. The latter mill includes a hydraulic shear for cutting slabs in lengths up to 6 m. The rolled slabs have a weight from 3.5 to 8 metric tons, a thickness from 100 to 200 mm, and a width up to 1550 mm.

Slabs are allowed to cool and are then scarfed in the usual manner. One interesting feature of that operation is the use of a portable ultrasonic testing machine which has been especially adapted to testing the soundness of slabs. The machine is used to check the soundness of the top of each slab.

## Three slab heating furnaces of modern design

The ATH plant has recently put into operation its third slab heating furnace designed by Rust Furnace Co. Each has a hearth measuring 6.6 x 28.8 m and an hourly heating capacity of 100 tons of slabs. Slabs are heated to 1280°C by a mixture of blast furnace and coke-oven gas. Furnace regulating instruments are of Minneapolis-Honeywell manufacture.

## The 66-in. continuous hot strip mill

The new continuous hot strip mill, built by German rolling mill manufacturers, is the only one of its kind in Germany, and thus it fills a considerable gap—even a chasm—in the counrty's steel output.

The mill has a capacity of almost 2 million tons of strip in widths up to 1500 mm. The hot strip mill includes a scale breaker followed by four roughing stands—three with vertical rolls—and six finishing stands, all of 1700 mm roll length.

The roughing stands are located 16 m, 24 m, and 39 m, respectively, from each other. Each mill is operated by a three-phase synchronized electric motor of 4500 metric horsepower. The slab is rolled to a thickness under 18 mm, while its length is increased to 54 m.

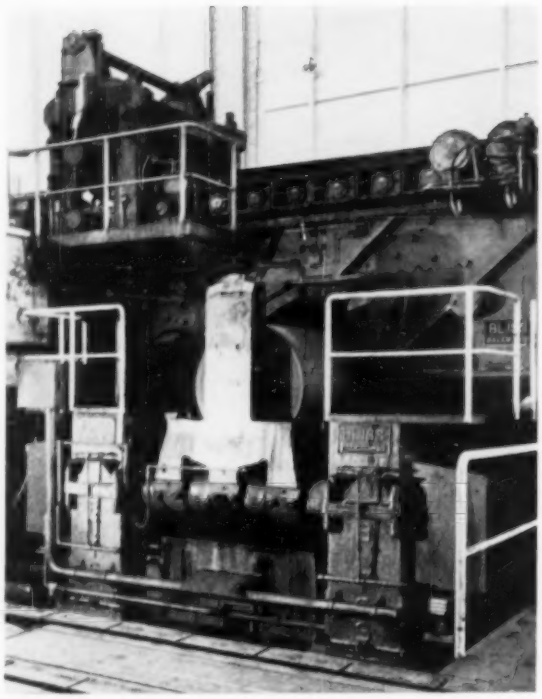
The six finishing stands are preceded by a rotating cropping shear and a scale breaker. Each stand is driven by a 5000 metric horsepower direct-current motor. Upon leaving the last stand at a speed of 10 m per sec, the strip has a thickness from 1.5 to 6.5 mm and a length up to 600 m; it is coiled on one of the two down-coilers built by E. W. Bliss Co. A third down-coiler is on order.

For the production of hot-rolled sheet, coils are uncoiled on a McKay machine and passed through a shearing line made up of a flying shear built by Wean Engineering Co., a McKay leveler, and a Wean edge cutter. The line is powered by General Electric motors. A second Wean flying shear for gages up to 10 mm is on order.

## Cold-rolled sheets produced on American equipment

The four-stand cold reduction mill—built by Continental Foundry & Machine Div. of Blaw-Knox Co.—permits the production of cold reduced coils at a rate up to 15 m per sec. The rolls of the mill have a length of 1680 mm and a diam of 530 mm. During the installation and trial runs of the mill, Thyssen worked closely with Armco Steel Corp.; Armco engineers gave on-the-spot technical assistance, while ATH mill personnel underwent special training with similar equipment at Armco plants.

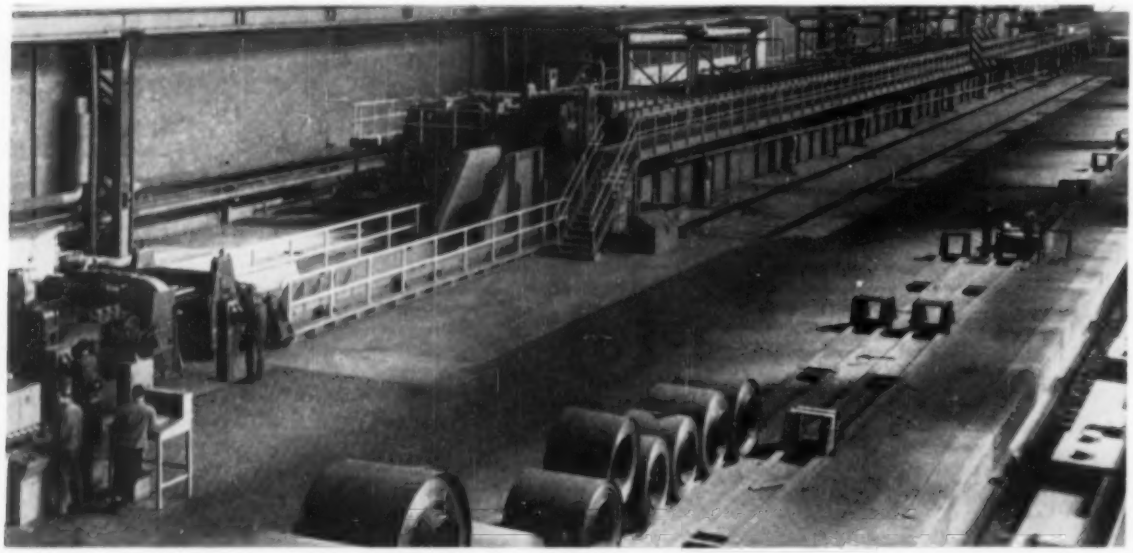
Prior to cold reduction, the hot-rolled strip is treated in an 85-m long Wean continuous pickling line; space has been provided for the installation of a second line at a later date. The line makes use of



One of the two down-coilers built by E. W. Bliss Co. for the Thyssen continuous hot-strip mill. A third down-coiler is now on order for this 2-million ton capacity strip mill.

McKay uncoilers and Taylor-Mansfield welding equipment to join together the ends of the coils.

Other equipment in the cold rolling department includes an annealing shop and a temper rolling mill built by Continental Foundry & Machine Div. Cold reduced coils from the temper mill may pass to one of two Wean shearing lines or to a Wean slitting line, both powered by General Electric equipment and making use of McKay uncoilers. Further equipment includes McKay levelers and Toledo scales for weighing the sheets.



Eighty-five meter long continuous pickling line built by Wean Engineering Co. for cold-rolled sheet mill of August Thyssen Hutte. Space has been provided for installation of a second line.

The entire cold reduction department is, thus, a demonstration of the ingenuity with which German engineers have adapted the latest types of American equipment to their production needs. The cold reduction plant is still not considered complete, and installation of additional equipment is planned, particularly an Armco-Sendzimir continuous galvanizing line.

## ATH, Built on coal, now imports from America

Since 1956, the Thyssen Hutte has again controlled some of its coal supplies through the purchase of interest in a Ruhr coal mining firm producing some 1.3 million metric tons of coal annually. But, even if the ATH were able to purchase the entire output of this firm, it would still be insufficient. Supply contracts with other Ruhr mines have been unable to meet the remaining requirements of the ATH with its present annual pig iron capacity of 2 million metric tons.

To make up the deficit ATH has been forced to rely on coal purchases made in America. Unable to exercise sufficient control over the costs of this important raw material, ATH resolved at least to have some control over the rates charged to move coal across the Atlantic. Thus, in 1956 ATH purchased a 10,000-ton capacity cargo ship—renamed the August Thyssen—to move coal from Virginia to the Dutch seaports. With evidence that German coal supplies would, in all probability, be in short supply for some time, this year ATH signed a contract for the building of a vessel of 15,000-ton capacity to be completed by the middle of 1958. A third ship of 17,000-ton carrying capacity will be ready by 1960. These ships will be able to carry not only coal, but also iron ore.

Another approach to the coal problem has been the organization of research projects to discover techniques for using some of the lower grades of Ruhr coal—the high volatile flame coals. A pilot plant has been set to make a so-called *erz-coke*, coke made from a mixture of finely ground high-volatile coal plus some 30 pct iron ore. About 10,000 tons of erz-coke was produced in one month, and a mixture of some 60 pct erz-coke and 40 pct normal coke has been successfully used in ATH blast furnaces. Attempts will be made to use 100 pct of the coke made from the coal-ore mixture.

## ATH expands beyond own plant to purchase interest in other firms

In order to provide a more diversified output, ATH has, during the past few years, purchased controlling interest in several German steel plants, all former units of the old Vereinigte Stahlwerke. The first move was the control of the Niederrheinische Hutte, German's largest wire producing firm. One object of this union was an intensification of the exchange of supplies in order to meet, in particular, Niederrhein's heavy demand for semis.

The second major acquisition was controlling interest in the Deutsche Edelstahlwerke—DEW—Germany's largest maker of alloy steels. This move will mean that ATH will not reconstruct its old electric steel plant, but instead all high quality steel production will be concentrated at DEW, which is expanding its capacity. Furthermore, this will permit the utilization by DEW of the continuous hot-strip mill at the Thyssen Hutte for rolling alloy steels.

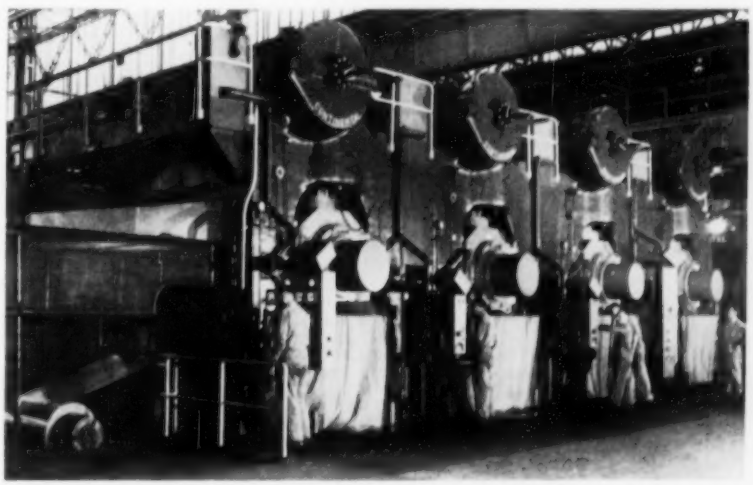
The third major transaction is the acquisition of minority interest in the Huttenwerke Seigerland, a large sheet and tinplate producer, and one of the principal customers of hot-rolled coils. In fact, some 40 pct of the present output of ATH's hot-strip mill is destined for the Siegerland firm.

The completion of the Niederrhein and DEW transactions creates for the Thyssen group a completely diversified line of steel products.

## ATH,Germany's largest and most modern steel producer

The new ATH group: the August Thyssen Hutte itself, the Niederrheinische Hutte, and Deutsche Edelstahlwerke, with a combined crude capacity of more than 3 million metric tons by the end of 1957, will be Germany's largest steel producing units and one of the largest of the European Coal and Steel Community. This is indeed a remarkable achievement when it is realized that only 8 years ago the ATH plant itself lay 80 pct destroyed.

ATH has stated that, "American know-how, equipment, and monetary loans have played a great part in this comeback story".



Four-stand cold reduction mill built by Continental Foundry & Machine Div. of Blaw-Knox Co. During installation and trial runs of the mill, Thyssen worked closely with Armco Steel Corp. Furthermore, ATH mill personnel underwent special training with similar equipment at Armco plants.

by F. Weston Starratt

# LOW-SHAFT BLAST FURNACE HOLDS NEW PROMISE

*With the successful operation of an experimental low-shaft blast furnace since 1954 in Cologne, Demag-Humboldt-Niederschachtofen GmbH is now building a 100-tpd furnace at the Klöckner Mannstaedt-Werke GmbH near the capital city of Western Germany. The design and operation of this furnace—utilizing briquettes containing ore, coal, and flux—is different from any previous low-shaft furnace. Although only design details are available at present,* JOURNAL OF METALS *hopes to publish a report on operation of the furnace in the near future.*

THE problem of producing iron from low-grade raw materials has been one which has been accentuated since the close of World War II by the industrialization fervor which has grasped the world. Today many countries with varying grades of iron ore deposits, but lacking adequate supplies of coking quality coals are desirous of establishing their own heavy industry, based on a domestic production of iron and steel. In many such regions, the demand for pig iron would hardly justify the heavy investment in the traditional blast furnace, even if the necessary coke were available. Furthermore, in some industrialized areas supplies of coking coal are becoming less adequate to sustain the desired level of pig iron production.

With these ideas in mind, work began several years ago in Germany on the design of a new smelting unit which could meet such requirements—low ton per year investment compared with the blast furnace, economic operation, use of some non-coking grades of bituminous coal and fine iron ores. Thus, in 1954 a 15-tpd low-shaft furnace was put into operation by a newly formed enterprise, Demag-Humboldt-Niederschachtofen GmbH.

## Basic principles of operation

The basic idea of the Demag-Humboldt low-shaft blast furnace is the simultaneous carbonization and reduction of briquettes made of a mixture of proper composition—ore fines or finely ground ores, fluxes, and non-coking bituminous coal with 30 to 35 pct volatile matter—to meet the demands of the desired type of pig. It is largely accomplished through the high temperature levels and the reducing atmosphere to which the briquettes are subjected soon after being charged into the furnace. These conditions make it possible to carbonize especially non-coking bituminous coals, resulting in a hard, porous briquette composed of intimately associated particles of ore, carbon, and flux. Such a briquette permits a rapid reduction of the metallic values in the ore.

Special care must be taken in the production of these briquettes, and a considerable effort has been put into perfecting the design of mixing and briquetting equipment, as well as achieving the optimum particle size and briquette dimensions.

## Economies enjoyed in initial investment

Not only does the low-shaft furnace carbonization process permit the utilization of most grades of non-coking bituminous coal, but also there are tremendous economies in initial capital cost which can be achieved. For the classical blast furnace the following plant is required: a sintering plant for treating fine ores, a coking plant, and the blast furnace with gas cleaning plant. But for the Demag-Humboldt low-shaft furnace only the following is necessary: a mixing and briquetting plant for fine ore and ground coal, and low shaft furnace with gas cleaning and tar condensation plant. It is at this time impossible to present exact cost figures for comparable capacity, but the probable economies are obvious. Furthermore, for a low capacity unit, a classical blast furnace with attending units could hardly be considered.

It must also be noted that the maximum capacity for the individual low-shaft furnace can not yet be estimated exactly. For reason of blast penetration, the small side of the hearth area-cross section is limited to about 2 m, but the broad side might be enlarged to 5 or 6 m, giving the individual furnace a capacity of about 150 to 170 tpd.

## The experimental furnace

It was in 1954 that the first experimental furnace and briquetting plant, incorporating these basic principles, was put into operation in Cologne, Germany. While it was only a unit capable of producing some 10 to 15 tpd of pig iron, it did nevertheless permit a considerable amount of pilot plant work to be done.

Particularly important was the successful operation of the furnace on all grades of coal from heavy volatile types to the hardest anthracite. However, because of its lack of volatile matter, the latter requires the purchase of a large amount of additional expensive pitch and renders therefore no economies, while the bituminous coals are self supporting in this way. Operation on brown coals was not carried out extensively, and while evidence indicates that a favorable operation is possible, further pilot plant tests are necessary and intended.

The furnace itself has an oval cross section with an area of 1.04 sq m and a useful cross section between the four tuyeres of 0.82 sq m. From the tuyeres to the charging mechanism maximum height is 3.2 m, although in actual operation the working height averages from 2.4 to 2.8 m. Experiments have shown that the actual carbonization period of the briquettes in the furnace is only between 25 and 30 min.

The gas cleaning unit is an important aspect of the low-shaft plant, for the utilization of high volatile coals means that considerable quantities of tar will be carried out of the furnace. Care must, thus, be exercised in maintaining the temperature of the gases during the dust collecting in order to prevent condensation of the tar. After removing the tar, the cleaned gas averaged some 1425 Kcal per std cu m. Its composition by volume was about 30 pct CO, 3 to 4 pct $CH_n$, 3 to 4 pct $CO_2$, 8 pct $H_2$, and 55 pct $N_2$.

## Some operating results

At the pilot plant furnace all types of bessemer, foundry, and open hearth iron were produced. All three types were of normal blast furnace composition, characterized only by generally lower sulfur content.

On the basis of 100 hr furnace operation out of one operating period of three weeks, bessemer grade iron containing less than 1.5 pct Si, less than 0.05 pct S, between 4.3 and 4.5 pct C, some 1 pct Mn, slightly more than 0.1 pct P, and 0.003 to 0.004 pct N was produced. Casting temperatures averaged some 1350°C, while slag temperatures were between 1400° and 1450°C.

Coal requirements, which averaged about 2200 kg of coal per metric ton of pig iron produced, can be considered satisfactory, particularly when compared with the coal requirements for sintering and coke production in a blast furnace of classical design. But in larger operating units lower fuel rates are anticipated, and it is expected that fuel requirements, calculated for comparison on the basis of coke with 85 pct C, will amount to some 1050 to 1200 kg per metric ton of iron produced.

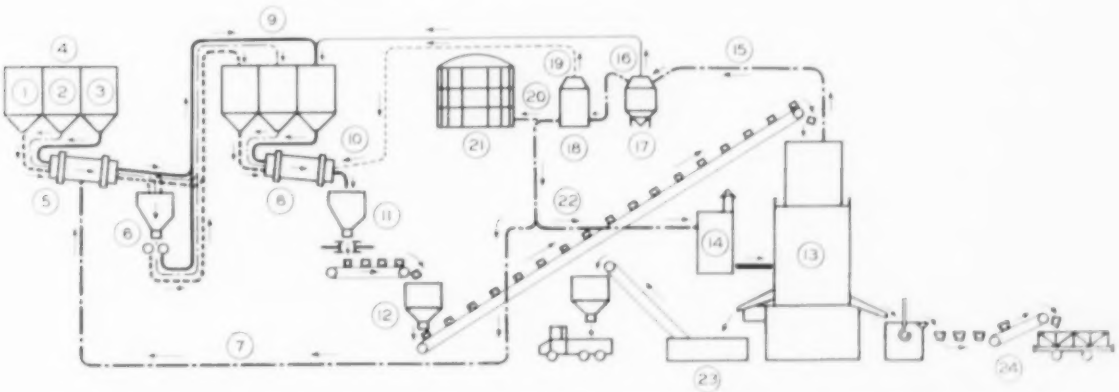
Operation of the experimental furnace was generally so satisfactory that it was decided to construct a much larger furnace which could be operated on an industrial scale. Such a furnace is now under construction at Troisdorf, not far from Germany's new capital city on the Rhine.

The Troisdorf plant, which looks back upon a history of 130 years, includes extensive hot and cold rolling mills, combined with a steel processing works. There also is an important pig iron foundry, and there was a blast furnace which was dismantled after World War II. The blast furnace auxiliary installations: ore stockyard, crane installations, ore bunkers etc. were not effected by the dismantling.

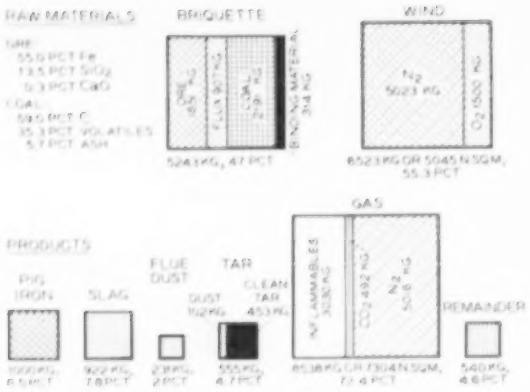
## The Troisdorf low-shaft blast furnace

Making use of the existing ore bridge and ore bunkers, the new low-shaft furnace will initially use minette ore from Lorraine, averaging under 5 mm; German and Swedish ore fines; and Ruhr gas flame coal of the same size. Primary crushing or grinding facilities are not planned for the unit. It is expected that during the course of operation various grades of ore and coal, possibly even brown coal, will be tried.

The entire operation of the plant is automatically controlled, with storage bunkers and the furnace itself constantly maintained at the proper level. Operation of the plant can be controlled from two




The low-shaft furnace at Klöckner Mannstaedt-Werke in Troisdorf, Germany. Numbers on the figure are as follows: 1—lime, 2—coal, 3—fine ore, 4—raw material bunkers, 5—drying plant, 6—hammer mill, 7—furnace gas, 8—mixer, 9—dry material bunkers, 10—tar, 11—briquetting press, 12—briquette bunkers, 13—low-shaft furnace, 14—wind heating unit, 15—furnace gas, 16—flue dust, 17—dust catcher, 18—gas cleaning units, 19—tar, 20—cleaned gas, 21—gas holder, 22—cleaned gas, 23—slag granulator, 24—casting machine.




**The material balance for the experimental low-shaft blast furnace at Cologne. The Troisdorf furnace is expected to show a similar balance.**

central control panels: one in the briquetting plant and one at the blast furnace. These provide the operators with all of the necessary information about each phase of the operation. Indeed, the plant can be said to be very much of a demonstration unit designed to show how a low-shaft blast furnace plant should be operated.

**Briquetting plant:** The briquetting plant is designed to supply the 100-tpd low-shaft furnace with three types of briquettes: those with excess coal, those with excess flux, and those with a lower portion of both coal and flux. It is in this manner that the furnace burden can be varied sufficiently to achieve proper performance.

Wet ores are fed into three *wet-bunkers*, which discharge into a Humboldt cylinder-type drier, fired by blast-furnace gas. The dried material is carried out of the drier by an air current and collected in a cyclone which feeds into the *dry bunkers*. Material coarser than 10 mm is not carried out by the air current, but instead it falls into a discharge hopper and is fed into a hammer mill for grinding to minus 5 mm. Flue dust from the low shaft furnace is also fed into the bunkers containing dried ore.

The proper mixture of ore, flux, and coal is automatically fed by conveyer belt into a cylinder-type mixer. Ground pitch is also added at this point as a binder for the briquettes. During the initial operation, this ground pitch must be purchased from the outside, but at a later date it will be added in liquid form directly from the plant's own tar converting unit. The mix drops from the mixer into a vertical cylinder heated by steam nozzles to 90°C so as to maintain the pitch in a pasty condition. From the steam heated mixer the mix is conveyed directly into the Humboldt briquetting press which is of design similar to presses used for briquetting coal fines. The press essentially consists of two slowly revolving cylinders with the briquet shapes on their outer surfaces; the mix is compressed between them.

At Troisdorf there are two parallel briquetting lines, each consisting of a mixer, heater, and press. The capacity of each press is 30 tons per hr of 110 g briquettes, measuring 40 x 45 x 55 mm.

Briquettes drop from the presses onto a cooling line which conveys them to the low-shaft furnace storage bunkers. The weight of the briquettes passing into storage bunkers is automatically recorded, and the level of the bunkers themselves is automatically controlled. The briquettes produced during the initial tests at Troisdorf have proven sufficiently strong to withstand storage.

**The furnace:** The 100 to 120 tpd furnace at Troisdorf is, as of this writing, completed and ready to go into operation as soon as all parts of the plant are complete. It is of rectangular cross section, measuring 4.2x2.1 m at the tuyere level; the height to the charging line is 4 m. It is lined with carbon bricks to the tuyere level and with normal blast-furnace refractories above this point.

There are ten tuyeres; four on each broad side, and one on each small side. These will supply the furnace with wind heated to 800°C—considerably higher than in the experimental furnace. The furnace will be blown at about 20,000 std cu m per hr; the blast pressure will amount to about 0.5 atm.

Furnace wind is to be heated in a recuperator-type unit fired by low-shaft furnace gas. The apparatus includes two bundles of alloyed steel pipes through which the hot flue gases pass to the burners. There are two gas burners fired at the rate of 2800 std cu m per hr per burner, which corresponds to about 25 pct of the gas produced by the low-shaft furnace.

The furnace is charged by a conveyer which is operated automatically so as to maintain the stock in the furnace at a constant level. Charging into the furnace is effected through four Humboldt gas-tight drum-type charging units.

The pig iron—generally Hematite and foundry pig—will at first largely be cast in a pig machine, although at a later date provisions will be in order for supplying the foundry with liquid metal.

**The gas cleaning plant:** In the other main part of the furnace—the gas cleaning plant—from 6000 to 7000 std cu m of gas per metric ton of pig, is to be treated in a manner similar at the experimental furnace, i.e. maintaining it above 360°C through the insulated dust catcher, followed by two pre-cooling units with warm water sprays, where some tar and dust are collected in the form of mud in the pits beneath. The gas, leaving these units at about 80°C, passes into two disintegrators for tar collecting, followed by two drop catchers. The gas, containing 2 g dust per std cu m, then enters the final cooling unit, in the lower part of which the light oils are separated from the cooling water. Then the gas, having now reached 25°C, is passed on to the second cleaning stage, consisting of one disintegrator and one drop catcher, where it is cleaned to 0.02 g per std cu m. The first cleaning stage is laid out for 22,000 std cu m per hr each and will require some 500 hp together, while the second stage is laid out for 30,000 std cu m per hr and will require 260 hp.

A tar recovery plant is being built, but it is not expected to be in full operation until sometime next year.

Troisdorf expects to operate the entire low-shaft furnace plant on a three-shift basis with a total crew of about 60 to 70 men.

## The future

With the prospects for a successful operation of the Troisdorf furnace from a technical standpoint and the possibility of making a favorable detailed cost analysis, it can be expected that additional units may be erected, particularly in the newly industrialized countries.

Summary of Articles

by Rudolf Graef, Walther Dick, and Ludwig Von Bogdandy

# ROTOR STEELMAKING PROCESS

*The recent revolution in steelmaking brought about through the development of low-cost tonnage oxygen has resulted in yet another new steel producing technique. The rotor process, now in the plant-scale operation stage at Oberhausen in Germany, may hold the promise of economic production of open-hearth grades of steel from plants supplied with widely varying types of iron ore.*

FOR over one hundred years the story of steel has been a dynamic history of continually mounting production to fill the needs of the smoking factories of this ever more industrialized world. This production marathon has been more than accentuated since World War II, and today with capacity generally being forced to the limit, the world is anxiously searching for new and more economic production techniques designed to make use of widely varying raw materials.

## Statistical analysis cries for new process

In Fig. 1, W. Dick and K. Daeves show in graphical form the development of ferrous production techniques in western Germany since 1800, with some projection to the year 2000, thus output on a logarithmic scale for a 200 year period. This presentation clearly shows that three distinct types of ferrous production have been practiced: first, charcoal iron, reaching its peak about 1840; second, puddle iron reaching its peak about 1880; and third liquid steel without the use of oxygen. The output of each of these methods has followed an exact parabola on the logarithmic scale, and the production of liquid steel without the use of oxygen has now reached the peak of its parabolic path.

Whether or not there be some underlying law—it could be called the parabolic law of production, for it is found in fields other than steel—it would seem from this statistical presentation of the history of steelmaking that a new technique of steel production must certainly be developed. And this is actually the case! During the past few years the production of liquid steel without the use of oxygen has fallen off as oxygen steel producing techniques have been introduced.

Today in Europe the standard of steel quality is based more and more on open-hearth grades. For some years the proportion of converter steel in Europe has been declining steadily, but the grades of iron ore available, the lack of adequate scrap supplies, and the fuel requirements of the open hearth prevent a complete change-over to the open hearth. Thus what is required in Europe is a steel producing technique, not heavily dependent upon scrap and with low fuel requirements, capable of producing steel of open-hearth quality or better.

RUDOLF GRAEF, WALTHER DICK, and LUDWIG VON BOGDANDY are with the Huttenwerk Oberhausen AG., Oberhausen, Germany.

## Requirements for a new steel process

All of the requirements for established steel producing methods—low capital and operating costs, suitability for mass production, and the production of high quality steel—remain valid for any new technique. There are, however, a number of improvements in the converter process which a new oxygen steel producing technique must solve.

**1) Heat Economy:** Fig. 2 shows the theoretical heat available in the converter from the oxidation of the elements in an average basic converter pig iron, containing 3.65 pct C, 0.4 pct Si, 1.3 pct Mn, 1.75 pct P, and with the oxidation of 2.65 pct Fe. Some 501,000 Kcal could be available from every ton of pig iron, but in the converter process the greater part of this heat is lost. This is largely because very little of the exothermic oxidation of CO to $CO_2$ takes place within the converter itself; this heat, amounting to 200,000 Kcal, is wasted regardless of whether the traditional converter practice is used or some type of oxygen blowing. Due to this loss, pig iron must contain at least 1.60 pct P in order to provide sufficient heat for casting.

**2) Flexibility of operation:** A new steelmaking process must have a wide degree of flexibility, being not only adapted to the use of wide range of raw materials, but also being capable of producing different grades of steel. A large number of western European mills are forced to rely upon supplies of ore purchased abroad from a large number of mines

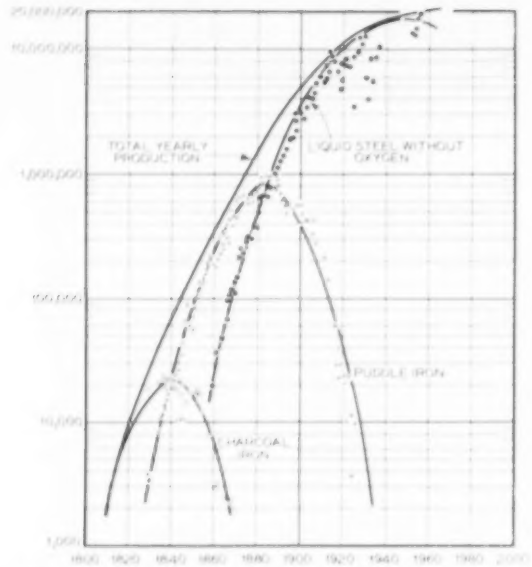



Fig. 1—Two hundred years of German steel production on a logarithmic scale. Major producing techniques follow an exact parabolic path and point to the introduction of a new technique today.

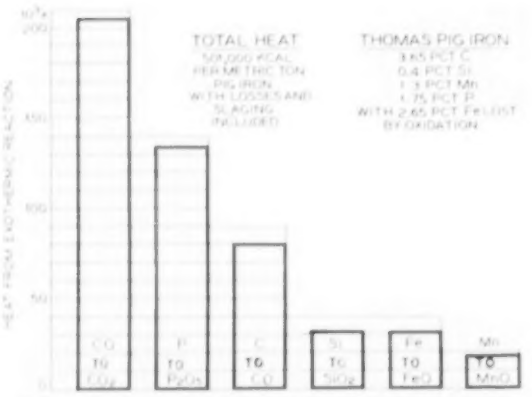



Fig. 2—The heat available from the exothermic oxidation of various elements shows that the greatest amount of heat is created by the burning of CO to $CO_2$. This heat is lost in all steelmaking operations except the rotor process.

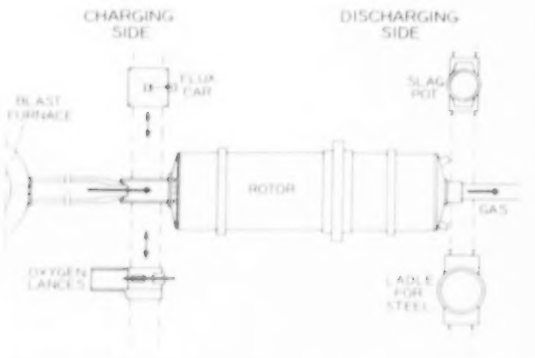



Fig. 3—Pig iron may be charged directly from the blast furnace into the rotor at Oberhausen. It is capable of producing open-hearth grade steel from varying grades of iron.

and transported long distances. The chemical analyses of such ores vary widely, resulting in pig iron with any percentage of P, Mn, and Si, and with a comparatively high content of S. If advantage is taken of all the possibilities which the international market offers, pig iron grades containing from 0.5 to 1.7 pct P will be obtained. Such pig iron, however, is not desirable for the open hearth process and is hardly suitable for the orthodox basic bessemer process.

**3) Dust control:** Dust in the brown smoke of the converters is very fine grained and therefore difficult to separate. What is needed is a process which either produces less dust or dust of a larger particle size. Hot, though undiluted, reaction gases produce the best condition for the formation of dust particles of a large particle size.

## The rotor process of Oberhausen—an answer to many steelmaking problems

In order to solve many of the problems faced at the Huttenwerk Oberhausen—particularly that of the economic production of open-hearth quality steels from pig iron of varying composition—development work began some years ago on the use of oxygen in steelmaking. Treatment of pig iron in a mixer as well as treatment of the steel bath using oxygen lances in the open hearth furnace turned out to be less promising than anticipated, because the life of the refractories was unsatisfactory. Engineers at Oberhausen then turned to the possibilities offered through the use of a rotating vessel.

In a casting bay, installation was made of a rotary, horizontal, cylindrical vessel, sufficiently large to receive the whole tap of the adjoining blast furnace, amounting to 60 tons—Fig. 3. The vessel has an overall length of 14.6 m, inside diam of 2.7 m, and outside diam of 3.7 m. There are openings in the end walls: one in the front for charging as well as the injection of the oxygen lance, and one in the rear for tapping, removal of waste gases, and flushing of slag. The speed of rotation is infinitely variable between 0.1 and 0.5 rpm. The rotor lining comprises two layers: a tar-dolomite layer rammed over a permanent magnesite lining of 120 mm thickness. Rings around the front and rear end openings are made of chrome-magnesite brick. After the first large-scale experimental program, the rotor was furnished with a tilting device to facilitate tapping. Fig. 4 shows the rotor in operation.

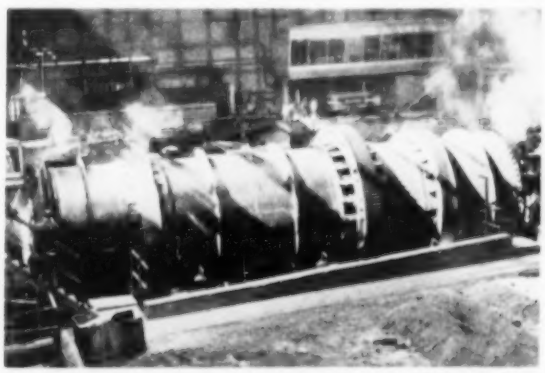


Fig. 4—The 60-ton rotor in operation at Oberhausen. Installation is now being made of a second rotor, this one of 100-ton capacity.

The oxygen feed has been arranged in such a manner that the rotor is supplied with two separate streams—primary and secondary oxygen—which may be controlled independently. Primary oxygen is introduced beneath the surface of the metal bath through a water-cooled blowpipe, thereby ensuring oxidation and stirring of the bath. For burning the CO, evolved during the refining process, secondary oxygen is directed over the surface of the bath—Fig. 5.

## The Rotor—to prerefine pig iron

When producing basic pig iron for the open hearth from pig iron of any phosphorus content, lime and ore are first fed into the preheated rotor through the charging hole. About 60 tons of pig iron are then added from the blast furnace through a portable runner; after the removal of this runner, the blowpipe carriage is brought up, and the blowpipes are put into position within the rotor. Following a blowing time of about 40 min, the major part of the slag is removed, and prerefined basic pig iron, containing about 1 pct C, is tapped for transfer to the open hearth.

## The Rotor—steel from low-phos iron

The refining of low-phosphorus pig iron to finished steel is similar to the production of prerefined metal so far as the operational practice is concerned. The refining process is completed as soon as the required carbon content is reached.

## The Rotor—steel from high-phos iron

For refining high-phosphorus pig iron to produce steel, the double slag process is used. When the bath contains about 2 pct C and only 0.1 to 0.2 pct P, then a low-iron, high-phosphorus slag is drawn off and ground to make thomas phosphate. With burnt lime and ore additions a second slag is prepared for dephosphorization. Under this slag, refining is brought to an end, and the finished steel is tapped into the ladle. This secondary slag remains in the rotor, being used as primary slag for the next heat after the addition of lime and ore. The time between tappings is about 2 hr: 15 min for charging ore and lime, 10 to 15 min for charging pig iron, 50 to 60 min blowing time, and 10 min each for the removal of the slag and the tapping of steel.

## Dephosphorization more rapid

During the first third of the blowing time dephosphorization proceeds in advance of decarburization in the rotor. Rapid dephosphorization is promoted by early formation of a highly reactive slag, which in turn is dependent upon fast melting of lime and the utilization of a large quantity of ore in the furnace. Both are the result of the high operating temperatures in the rotor. Fig. 6 provides a comparison with normal converter and oxygen-enriched converter practice.

Combustion of carbon monoxide and the resulting rise in temperature in the rotor have a positive effect on the refining rate, partially due to the greater ore additions. But the speed of refining also depends on the quantity of gaseous oxygen supplied, and the stirring effect caused by the injection of primary oxygen and the rotating action of the vessel. Furthermore, a considerable penetration of secondary oxygen into the metal is obtained where the bursting CO bubbles and the simultaneous displacement of slag causes an immediate contact with the oxygen atmosphere in the rotor.

## Desulfurization effective

Desulfurization in the rotor is much more efficient than in the basic bessemer converter or in the open-hearth furnace—Fig. 7. Reasons for this are the high temperature of the slag as well as the immediate contact between the metal and the oxidizing, sulfur-free atmosphere. Suitable conditions are created for a partial oxidation of sulfur, which can be confirmed

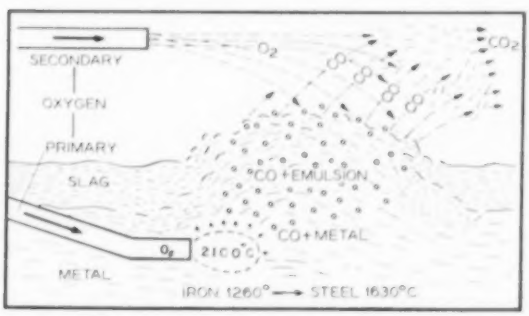



Fig. 5—There are two oxygen lances used in the rotor, one submerged in the bath to refine the iron and the second above the bath with relatively impure oxygen to burn the CO.

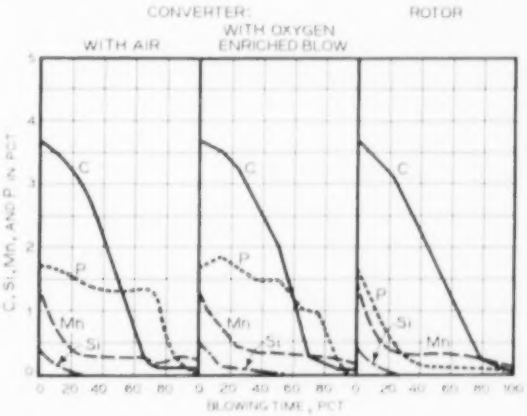



Fig. 6—Blowing curves for different processes operating on basic-bessemer iron. The rotor shows more rapid early dephosphorization.

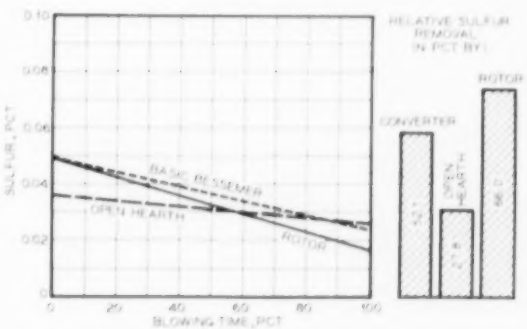



Fig. 7—Desulfurization, a comparison between the rotor and other steelmaking processes shows the high efficiency of the rotor method.

by analysis of the waste gases. The sulfur balance between pig iron and the other raw materials on the one side, and steel and slag on the other, shows a deficit of about 15 pct, which corresponds to the amount of sulfur oxidized. The suitability of the process for the treatment of pig iron of increased sulfur content was clearly demonstrated, and extra provisions for the removal of sulfur are not necessary. The low sulfur content of the steel is remarkable; the maximum is 0.012 pct S.

## Slag relatively low in Fe

Before starting a new heat, ore and burnt lime are added to the residual slag in the rotor; in this way the slag is enriched to about 37 pct Fe and 40 pct CaO. Refining causes a heavy reduction in the iron content, and early dephosphorization quickly enriches the slag in phosphoric oxide.

When the metal has reached about 2 pct C, some 50 pct of the iron from the ore has been reduced so that the slag still contains approximately 17 to 18 pct Fe. At this moment it is necessary to limit the speed of oxidation for a few minutes so that further reduction of iron is obtained before tapping the slag. Together with the high temperature reserve within the rotor, the slowing down of the oxidation rate ensures a sudden sharp reduction of the iron content of the slag, reaching limiting values of 4 to 5 pct Fe. With this low Fe content the degree of fluidity of the slag is heavily impaired, and at present from 8 to 12 pct Fe in the primary slag is regarded as economically and metallurgically permissible.

The primary slag contains 18 to 20 pct $P_2O_5$. Under the secondary slag the 0.1 to 0.2 pct P in the metal is cut to less than 0.030 pct. Rephosphorization has not been noticed.

## High slag temperatures

Thermocouple measurements showed that on the average the slag temperature is about 40°C above the temperature of the steel bath. This is analogous to the open hearth, but contrary to the converter. The burning of CO in the rotor results in flame temperatures of more than 2000°C, which is higher than in the open hearth furnace. Theoretical estimation of the heat transfer shows that 60 pct of the heat arising from the burning of CO is absorbed by the bath. This high heat absorption of the bath is promoted by a bath length of 13 m.

When using the air-blown converter only 33.2 pct of the heat is utilized and the remainder is lost in heating nitrogen ballast, escaping CO, and heat radiation. The corresponding figure for a blast enriched to 30 pct O is 42.9 pct, and for the rotor it is 75.2 pct.

## Greater direct reduction of ore

The higher operating temperature permits a considerable quantity of iron ore to be charged, thereby providing for a higher degree of direct reduction than is generally possible with other techniques. As has been pointed out, high furnace temperatures directly and indirectly promote early dephosphorization, speed-up of refining, and promote effective desulfurization. Furthermore, since combustion of CO develops more heat than the oxidation of phosphorus, the hitherto usual principal heat producer, the process is not limited to a certain phosphorus content of pig iron.

As cooling ore, practically any oxidic iron material with more than 50 pct Fe may be used. Fines, concentrates, and mill scale may be used advantageously. Under local conditions, replacement of cooling ore by scrap may be desirable.

The iron yield—iron contained in the molten steel divided by the total iron contained in the charge—is 97.8 pct for the rotor process including dust recovery, 96.9 pct for the basic bessemer process without oxygen addition, and 95.3 pct with oxygen enrichment. The low pig iron consumption of the rotor—997 Kg per metric ton of steel—results from the favorable utilization of the iron as well as the high ore imput—100 kg of iron per metric ton of yield.

## Lime consumption

Consumption of lime amounts to 125 kg per metric ton of steel and is somewhat lower than for the basic bessemer process. When pre-refining basic pig iron it is reduced to a minimum of 20 kg. Instead of burnt lime, crushed limestone may be used without detrimental effect; however, in this case the ore charge must be reduced to compensate for the dissociation heat of limestone.

## Oxygen Consumption

Total consumption of oxygen per ton of steel amounts to 90 std cu m, a third of which is used for the burning of CO. Some 27 std cu m of $O_2$ are fixed in the ore and introduced with it. The rest, 63 std cu m is supplied by gaseous oxygen. Assuming a 90 pct utilization, about 70 std cu m $O_2$ will be needed per metric ton of steel. The distribution between primary and secondary oxygen is at present in the ratio of 1:4. The secondary oxygen has a purity between 70 and 90 pct, but by preheating its concentration may be reduced. By raising the preheating temperature to between 800° and 1000°C, which may be done in the exhaust duct with the help of a regenerator, secondary oxygen may be replaced by an air blast.

## Dust control not a problem

Pneumatic steelmaking practice has generally been troubled with the problem of air pollution and dust control. Oxygen enrichment techniques, including the oxygen lance or LD process, have resulted in a considerable increase in the problem of dust removal, largely due to the finer particle size.

As a possible means of dust removal in the LD process, a suggestion has been put forth for heating the gases to 2000°C to vaporize the iron particles, then following with slow cooling so as to prevent any sudden oversaturation of metal vapor. The frequency of nucleus formation would be low and the resulting particle size large. This complex method of enlarging the particle size of steelmaking dust is easily realized in the rotor process, for the burning of CO, provides the necessary heat for maintaining the iron vapor in an undersaturated state, while the slow passage of gases through the rotor into the flue system permits the slow cooling necessary for the formation of large particles.

The waste gas is exhausted through one pipe immediately adjacent to the rotor and is purified in a simple dust collecting plant. Electronic microscope pictures showed that this comparatively simple method of dust removal is possible because of the linear particle size is on the average 4 to 5 times

that of dust particles from the converter, while the particle weight is almost 100 times greater. The iron-rich dust collected is recirculated to the rotor as raw ore feed. See Fig. 8.

## Process control automatic

With regard to the measuring and controlling technique, great importance was attached to the knowledge of the laws of reaction kinetics, so that controlling pulses could be derived for practical use. The decisive factor of measurement is the CO content of the waste gases. For each phase of the process the CO content is the indicator of the main variables, namely refining velocity, heat utilization in the vessel, and iron content of the slag.

The CO content is influenced by the depth of immersion of the primary blowpipe into the metal as well as by the ratio of primary to secondary oxygen. This interdependence permits automatic control in an easy and safe way. Further possibilities of control arise from the adjustability of the speed of revolution of the vessel and the type of oxygen feed.

## High quality steels rotor produced

According to the experience gained at Oberhausen, the rotor will probably be used in an integrated steel works to relieve open-hearth mills with production programs which are often more versatile than in the U. S. The rotor may well take over the field of quantity steels with high quality requirements. It could be used for melting special structural steels, e.g., shipbuilding steel, unalloyed boiler steel, as well as high-quality semi-products for steel wire, strip, sheet, and bars. Its proper domain is steel with a carbon content between 0.05 and 0.25; however, there is no objection to increasing this to 0.8 pct C.

From the temperature point of view, optimum conditions are provided for deoxidation. The oxygen content in finished steel amounts to 0.005 to 0.015 pct which compares favorably with highest quality open-hearth and electric-furnace steel. In addition, the nitrogen content of fully killed rotor steel averages 0.004 pct, without showing any noticeable spread.

## Lining life seems satisfactory

Thus far at Oberhausen the lining life has been quite satisfactory, except in the immediate blowpipe area. At this weak point the new tilting rotor will enable the operator to work with an increased depth of the bath. Then flow conditions will be improved so that a normal wear of the lining can be anticipated. Moreover, the easier discharging of the tilting rotor will facilitate the patching of damaged linings, as is the case with the open hearth furnace.

## Estimated capital and operating costs

**Capital costs:** At present, operational results can be given only approximately. Investment costs have been estimated at about $24 per metric ton per annum for a rotor steel works with a yearly production of 600,000 tons—buildings and cranes included. This figure corresponds to the costs of the conventional basic-bessemer steel works, while approximately $34 was calculated for an open-hearth installation.

**Labor costs:** The daily production of a 100-ton rotor may be estimated at 1000 to 1200 metric tons of steel. For operating an installation of two 100-ton rotors, 23 men per shift will be necessary so that wages to the amount of 0.3 man-hr ton may be assumed for melting. The number of personnel for the pitside will be not more than 0.2 man-hr per ton of raw steel. For the ancillary installations about 0.50 man-hr per metric ton may be required. Thus, the total expenditure will not surpass 1 man-hr per metric ton of steel.

**Other operating expenses:** At the present life of the lining, the consumption of tarred dolomite plus sintered dolomite for patching will be approximately 50 kg per metric ton of raw steel. With the mechanical modifications of the rotor planned, less than 35 kg will be a safe estimation, which is by no means more than the consumption of dolomite in the open hearth. Maintenance costs seem to be less than for the basic-bessemer steel works, since the mechanical parts of the rotor are not heavily taxed.

Oxygen consumption has already been given as 70 std cu m per metric ton of steel. This figure will be raised by 5 or 10 cu m when including the oxygen which is necessary for heating up the rotor after shutdown and during repairs. The normal working pressure is 4 atm gage, ahead of the blowpipes.

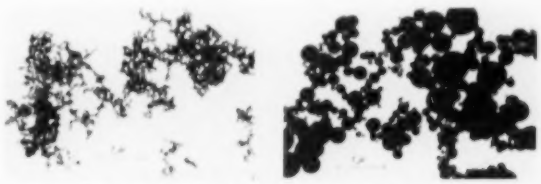


Fig. 8—The electronic microscope shows dust particles from the rotor, right, to be on the average 4 to 5 times the linear size of dust particles from the basic converter, left.

The process costs are definitely less than the corresponding costs of the open-hearth steel works and may be comparative to the process costs of the basic bessemer steel works.

## Future prospects

In addition to the 60 ton rotor steelmaking unit already in operation at Oberhausen, a 100 ton unit is now under construction and should be in operation shortly. Its successful operation can well be expected to provide the impetus for similar installations elsewhere.

The South African Iron & Steel Industrial Corp. has announced plans to install rotor steelmaking plants at its Vanderbijl Park and at its Pretoria works, thereby increasing the firm's crude steel capacity by some 600,000 tons annually. These rotors —50 ft in length and 15 ft in diam—will treat 100-ton heats. Furthermore, it is reported that in the reconstruction work taking place at the Burbach steel plant in the Saar, operated by the ARBED firm, sufficient space has been provided for installation of two 100-ton rotors.

There has, thus, already been a positive response by the steel industry to the rotor steelmaking process.

## References


[1] Rudolf Graef: *Grundlagen und Ergebnisse des Stahlerzeugung im Rotor*, Stahl u Eisen, No. 1, Jan. 10, 1957.

[2] Remarks made by Walther Dick to the Verein Deutscher Ingenieur, July 5, 1957 in Siegen, Germany.

[3] Ludwig von Bogdandy: *Untersuchung uber den simultanen Ablauf von Tropfchenkeimbildung und -wachstum, erlautert am Beispiel der Staubentstehung bei pneumatischen Stahlfrischverfahren*, Zeitschrift fur Elektrochemie, vol. 1, 1957, pp. 222 to 228.

by Bo Kalling, Sven Eketorp, and Sven Backstrom

# SWEDEN: IRON POWDER TO ROLLED STEEL IN ONE OPERATION

*Granulated pig iron is decarburized with iron oxide, and the low-carbon product is rolled directly to compact steel. Called the Stora Powder Steel Process, it was developed by the Research Department of Stora Kopparbergs Bergslags A/B, Sweden.*

RAW material for the Stora process is a normal open-hearth pig iron, in which the silicon content is brought down to the lowest possible value by prerefining with oxygen. The pig iron is granulated in an air-water stream to a particle size that may be as high as 3 mm. The powder is mixed with a high grade iron-ore concentrate in a mixer, and the powder mixture is packed in a box of sheet steel, in which holes are provided to allow the reaction gas produced during decarburization to escape. The box is heated in a suitable furnace to about 1100°C until the reaction between the oxide and the pig iron is completed. When the gas evolution stops, the hot box with its contents of sintered iron powder is rolled in a conventional mill.

## Similar processes

There are other processes which have some resemblance to this method. In the RZ-process (Roheisen-Zunder) developed in Germany for the production of iron powder, pig iron is granulated to a very fine particle size with high pressure air.[1,2] During granulation, the iron droplets are partly oxidized, and the particles get an oxide surface layer surrounding a center with high carbon content. In the succeeding decarburization, oxygen at the surface reacts with carbon in the center to an end product of soft iron with low contents of carbon and oxygen. The mass of powder is slightly sintered together during decarburization and is made into iron powder by a not-too severe grinding. Of interest in this connection is that the iron powder can be rolled to strips in a cold rolling operation, followed by successive heat treatments and rollings.[3,4]

At Ontario Research Foundation in Canada, P. E. Cavanagh has developed a method for gaseous reduction of iron ore concentrate to sponge iron, which may be rolled out to steel directly after reduction.[5,6] In such a process, however, it must be difficult to arrive at the extremely high degree of reduction that is needed, and also to obtain such a pure concentrate that the gangue content of steel will not be too high. When using concentrate as raw material, the amount of concentrate is 140 pct of steel weight, while the Stora process uses only about 15 pct because the raw material is largely pig iron.

As compared to the above mentioned processes, the Stora powder steel method has the advantage that it produces a clean steel directly from pig iron and concentrate using a conventional heating furnace, since the powder mixture is enclosed in a steel sheet cover. With this simple method it has been found possible to make steel with the desired carbon content and, at the same time, a low amount of oxide inclusions. The quality of the steel is quite comparable to ingot steel.

## Pig iron is prerefined

The hot metal, from an electric low-shaft blast furnace, has the following average analysis: 4.3 pct C, 1.1 pct Si, 0.9 pct Mn, 0.045 pct P, and 0.040 pct S.

Prerefining of the pig iron has been done in the ladle with an oxygen lance blowing down into the bath. This method is quite feasible when complete removal of silicon is necessary, but a rotating furnace is preferable. When prerefining in the ladle, the mixing action is limited, which results in a rather

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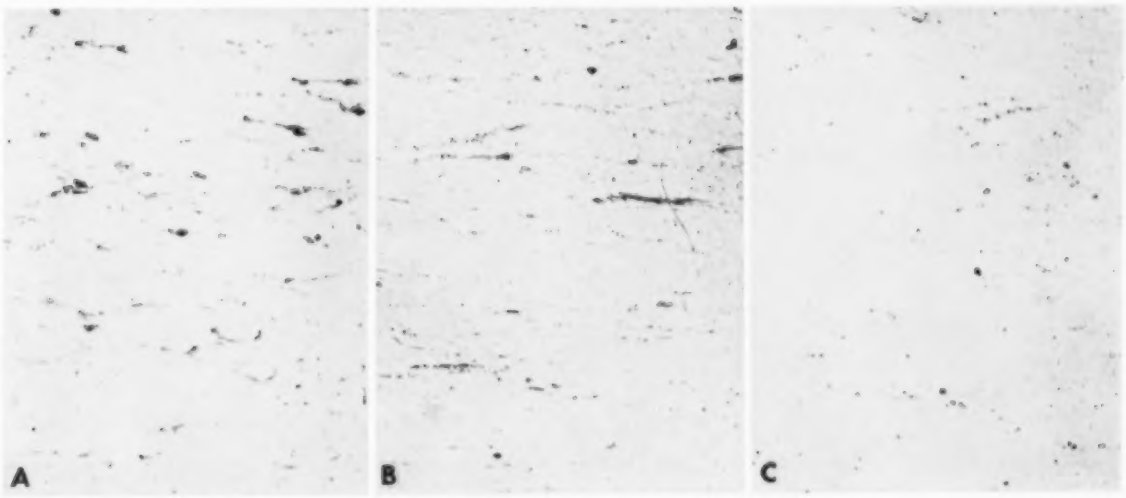


Fig. 1—Powder steel with a) 0.15 pct; b) 0.06 pct; and c) 0.02 pct Si. Not etched. 60X.

heavy loss in carbon together with a high iron content in the slag if all silicon should be oxidized. The Kaldo rotating furnace in Domnarvet, Sweden[4] has been found to be specially suitable for prerefining, and silicon contents of about 1 pct can be brought down to below 0.05 pct in 5 to 10 min. In this prerefining operation, it is preferable to use a lime addition such that the end slag will have a basicity of about 1.3, roughly the same as an ordinary blast furnace slag. The iron content will then be as low as about 3 pct. During blowing in the Kaldo converter, about 3 pct ore can also be added at a silicon content of 1 pct. Due to the amount of iron reduced from the ore, pig iron yield in the preblowing operation is above 100 pct. The carbon content decreases about 0.5 pct when blowing to Si<0.05 pct. This is, however, no disadvantage in the granulation and decarburization of the pig iron.

The reason why only the lowest possible silicon content can be allowed in this process is that the silicon is oxidized to $SiO_2$ during decarburization, and the silicates formed are precipitated on the surface of the original pig iron particles. The same has been found to happen in the RK-process.[1] Stora investigations have shown that the silicon content has to be brought down below 0.05 pct. Fig. 1a shows the structure of the steel—rolled as sheet bar—at 0.15 pct Si in the pig iron; the slag around the pig iron grain is clearly seen. At 0.06 pct Si (Fig. 1b the steel is definitely cleaner, and at 0.02 pct. Si the typical slag formation around the pig iron particles has disappeared (Fig. 1c). This picture gives an impression of the cleanliness that can be obtained in the steel. The slag present comes partly from the small amount of gangue left in the concentrate, and partly from oxides which have failed to react with the carbon in the pig iron.

Granulation has been done in such a way that pig iron was poured against a stream of air, water, or both, coming from a high-pressure nozzle. The particle size may be relatively coarse, and it is only necessary to go below 2 to 3 mm.

## Pure concentrate used

If iron-ore concentrate is used as the decarburizing medium, as pure a concentrate as possible must be employed. The concentrate used has been A-10, <0.2 mm from Malmberget, Sweden, which by dry magnetic separation on a Mortsell separator[5] has been cleaned to a $SiO_2$ content of only 0.10 pct. Total gangue content in the concentrate is 0.3 to 0.4 pct.

The amount of concentrate to be added depends on the carbon content of the pig iron; at 3.5 pct C it is 17 pct of the weight of the total mixture for a carbon content of 0.10 pct in the steel produced. The pig iron powder and the concentrate have to be thoroughly mixed before the mixture is placed in the box. Other oxide additions, as for instance mill scale, may be used, and it is also possible to supply the oxygen required for the decarburization by a previous oxidation of the pig iron powder. In this case, however, the yield will be decreased.

When making thin sheet as the final steel product, the box has the following dimensions: length 1000-mm, width 250 mm, and thickness 60 mm. This corresponds to a weight of 70 kg. Plate thickness has been 1 to 2 mm. As the steel cover will be a part of the end product, a certain amount of material has to be circulated in the process—about 6 pct when the sheet thickness of the box is 1 mm.

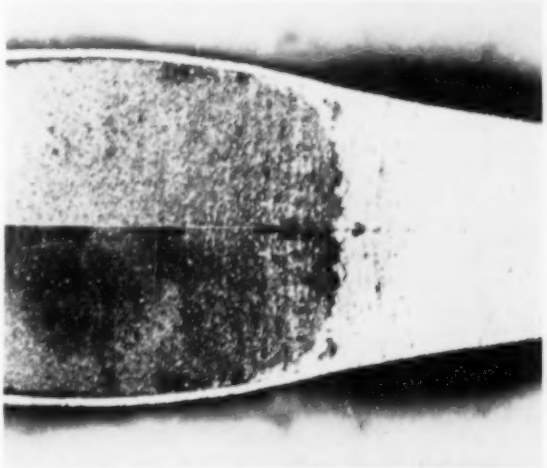

Fig. 2—Section of partly rolled box with powder. At left the porous powder mass, at right the rolled solid steel. 0.7X.

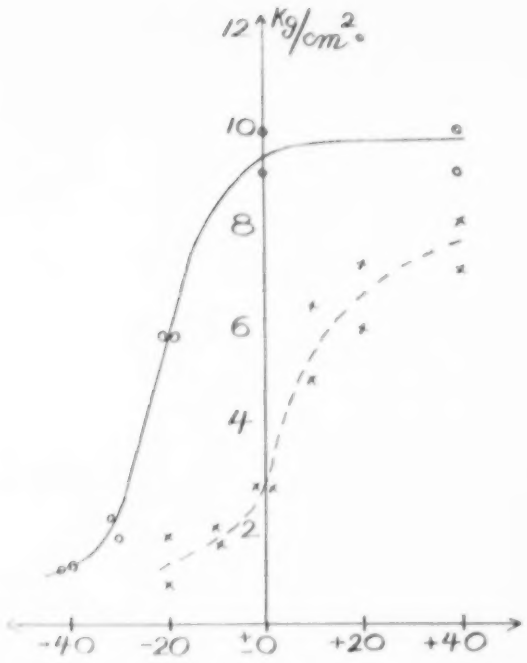


Fig. 3—Impact transition curves for powder steel, impact energy in kg per sq cm vs temperature, in degrees centigrade. The solid line represents a rolled and forged sample that was normalized at 950°C, and the dotted line represents a sample that had additional treatment of a 10 pct lengthwise strain and 6 hr of aging at 800°C.

Fig. 4—Bend test in weld of powder steel with 0.200 pct P.

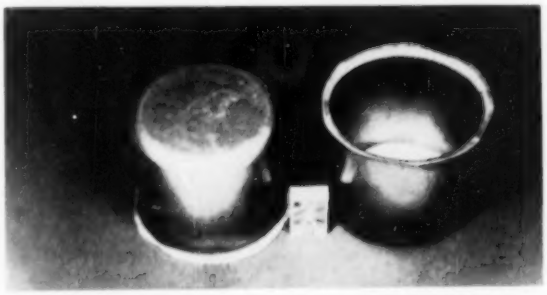

Fig. 5—Deep drawing test of powder steel. Sheet thickness 1 mm, plunge diam, 140 mm; diam before pressing, 304 mm.

## Non-oxidizing furnace atmosphere

After filling the powder mixture into the open box, a lid is welded on top of it. The weld does not need to be tight— and should no be so—as gas is generated during the reaction. The amount of gas is about 50 cu m per ton, and the analysis is 90 pct CO and 10 pct $CO_2$. Instead of openings along the weld, holes may be placed on the upper side of the box.

The decarburization is carried out at 1050°C, and the rolling, which is done directly afterwards, has usually been carried out after heating to 1200°C. It will probably be possible to lower this rolling temperature to 1050°C when larger units are used and the time between the heating furnace and the rolling mill is as short as possible. The furnace used has been a muffle furnace with Kanthal heating elements. In large-scale operation a continuous furnace of any normal type can be used. In spite of the sheet cover, an oxidizing atmosphere in the furnace will not be permissible, and thus, either direct heating with electric resistance or indirect with radiant tubes or other arrangements has to be used. The gas being generated from the powder mixture during decarburization will itself guarantee a strongly reducible furnace atmosphere. This gas may be burnt in the preheating zone, or still better in radiant tubes in the finishing zone.

## Longer heating time

Time necessary for the heating operation will be longer than for normal billet heating, partly due to the fact that the decarburization takes a certain time which is dependent on the diffusion speed of the carbon and the reducibility of the iron oxide, and partly because the mixture has a density of only 4.2, which slows up the speed of transportation of the relatively large amount of heat that is required. Heating will thus be more expensive than normal, in capital as well as operational costs. On the other hand, heating is the only really expensive part of the process, and it ought to be stressed that the heating in this case replaces both the heating up to molten steel temperatures in the steel processes as well as the normal heating of ingots. Total Btu-consumption for the process from pig iron to hot plate bar will, therefore, definitely be lower than for conventional steel processes; consumption for a gasfired furnace with a production of 15 tons per hr being calculated at 2,600,000 Btu's per ton. Total time for heating and decarburization will be 3 to 4 hr for the box thickness of 60 mm.

## Universal rolling mill employed

The box with the decarburized powder coming from the furnace at 1100° to 1200°C is rolled in a 750 mm universal mill with 520 mm side rolls on both sides. The small gas flames coming from the holes in the lid are formed when the gas is forced out of the box during rolling Fig. 2 shows a section of a piece where the rolling was interrupted. At the left is the steel sheet cover, 2 mm thick, with the porous mass of spongy iron, and to the right the rolled solid steel is seen, where the plate cannot be distinguished from the powder material. In order to get full density, the box with the powder has to be compressed to about half its thickness, but to get optimal strength the steel has to be rolled to at least ⅓ of the thickness at full density. This will mean that out of a 60 mm thick box a plate of maximum 8 mm thickness may be produced. One of the basic

ideas of the process is that the original thickness of the box should not be any larger than necessary, so that the least possible rolling has to be done. A pre-rolling, such as is done for instance in blooming mill, should be avoided in any case.

Another reason why a thickness greater than 60 mm has not been used is that with greater thicknesses it has been difficult to avoid a center with a higher carbon content. The explanation for this carbon enrichment, which follows the temperature gradient during heating, seems to lie in the fact the decarburization proceeds at different $CO:CO_2$ ratios in the waste gas at different temperatures. At the lower temperature in the center, the $CO_2$ content will be higher and thus the remaining carbon content—at a fixed addition of oxides—will be higher than at the surface. However, such a carbon gradient, increasing towards the center, does not always have to be a disadvantage, and may really be valuable for certain applications.

## Low oxygen steel

It was astonishing to find that it was possible to produce such a good steel with such a simple method. It is especially remarkable that the oxygen content during decarburization can be brought down to relatively low values at the same time as the carbon content can be fixed to the level desired. At 0.10 pct C in the steel, the oxygen content (determined by the vacuum extraction method) is about 0.10 pct. This is, of course, a high value in comparison to normal ingot steel, but in spite of this, the properties are good, which must be due to the fact that the slag inclusions in the powder steel are present in a quite different way than in normal steel. In ingot steel, the slag is concentrated to *isles* and larger bands, which appear rather distant from each other in a matrix with a low oxygen content. In powder steel, the slag is present as an impregnation throughout the steel structure. Powder steel has some resemblance to wrought iron, but the slag content is lower and more dispersed.

## Carbon >0.10 pct in steel

In order to arrive a 0.10 pct C in the steel an addition of 17 pct magnetite concentrate should be used at a carbon content of 3.5 pct in the pig iron. When the amount of concentrate is decreased, the carbon content of the steel is increased, and it is thus very simple to arrive at the desired carbon content. Carbon contents lower than 0.05 pct result in a rapid increase in the oxygen content, and therefore, the lower limit for the carbon content of powder steel should be set at 0.10 pct. The nitrogen content is low, about 0.002 to 0.004 pct. Sulfur is not decreased during the process, but sulfur content of the pig iron can easily be brought down to 0.010 pct.[10,11] As will be discussed later, phosphorus content may be higher in powder steel than normal without bad effects.

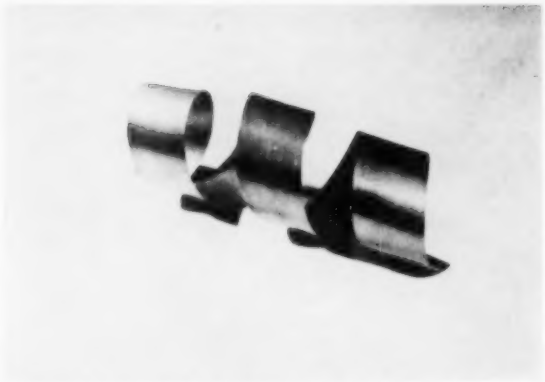

Fig. 6—Cold rolled strip of powder steel. Hot rolled from 13 mm sheet bar to 1.0 mm thickness and cold rolled from 1.0 to 0.23 mm without intermediary annealing.

Table I. Tensile and Impact Properties for Stora Powder Steel in Comparison to Electric Steel

| | Stora Powder Steel | Electric Steel |
|---|---|---|
| Analysis, pct: C | 0.13 | 0.13 |
| Si | 0.01 | 0.20 |
| Mn | 0.25 | 0.45 |
| Ultimate yield strength, kg per sq mm | 28 | 27 |
| Tensile strength, kg per sq mm | 41 | 41 |
| Elongation, pct | 31 | 28.5 |
| Contraction, pct | 65 | 65 |
| Max. impact energy, kg per sq cm | 10.6 | 12.5 |
| Impact transition temperature, °C | −25 | −40 |

Table I shows an example of the tensile and the impact properties of powder steel at a carbon content of 0.13 pct in comparison to killed electric steel with the same carbon content. The powder steel was forged from a sheet bar 70x13 mm to 13x13 mm. The two steels were normalized at 950°C.

Fig. 3 shows two curves for a powder steel in aged and non-aged condition. Generally it can be said that powder steel has about the same properties as killed electric steel, but impact properties are not quite as good. Possibilities for obtaining a still higher quality are at hand, and effort will be concentrated on decreasing the slag content still further. Powder steel behaves quite normally in welding.

## Free from segregations

An interesting advantage with the Stora Powder Steel Process is that the steel is free from segregations since it is produced directly from powder without melting. As phosphorus is one of the elements

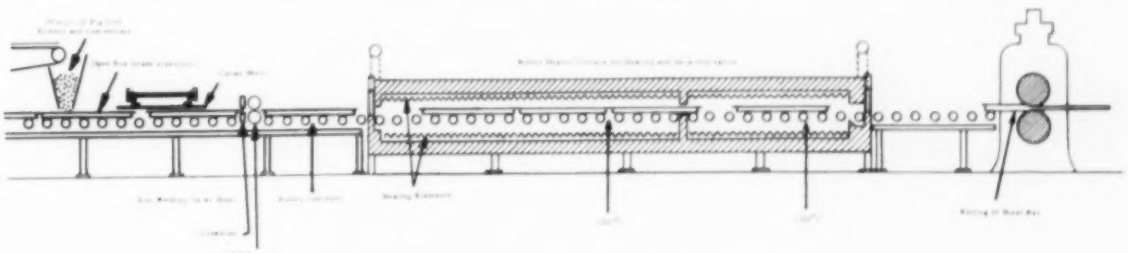

Fig. 7—Schematic sketch of full-scale powder steel installation.

that show the strongest tendency to segregation, it has been found possible to use pig iron with rather high phosphorus. Fig. 4 shows a bend test in a weld made with a powder steel analyzing 0.05 pct C and 0.200 pct P. In the form of 2 mm sheet and after normalizing at 1000°C, this steel showed the following data:

| | |
|---|---|
| Ultimate yield strength | 27.0 kg per sq mm |
| Tensile strength | 45.4 kg per sq mm |
| Elongation δ 10 | 25.0 pct |

So far, only unalloyed steels have been made; silicon, chromium, aluminum and the like are excluded as alloying elements, as they are oxidized in preference to iron. During the decarburization they will, therefore, be more or less completely oxidized. Possible alloying elements are, however, nickel, cobalt, molybdenum, and copper. Due to the fact that above all chromium is excluded, it seems as if the use of powder steel will be limited to low carbon steels.

## Flat products best suited to process

Sheet bars with a thickness of 13 mm and a width of 250 to 350 mm have been produced. In some cases these sheet bars have been rolled out to sheets with conventional methods. The sheet has been found to have excellent deep drawing properties. Fig. 5 shows some test pots from a deep drawing test for determination of the ratio D/d, where D is diameter of the flat sheet before pressing, and d is plunge diameter. Tests were carried out at Svenska Stalpressnings AB, Olofstrom. Sheet thickness was in this case 1.0 mm, plunge diam 140 mm, and D 304 mm. All tests carried out at this value of D were successful. The Erichsen value for this test was 11.0 mm. It was stated at Olofstrom that the powder steel behaved at least as well in pressing as American carbody sheet. In Fig. 6 a strip cold rolled from 1.0 to 0.23 mm without intermediary annealing is shown.

Stora has also made square and round sections. The flat products are, however, best suited for this process, as it is of advantage to have as large a surface and as small a thickness as possible during the heating operation in order to get rapid decarburization and efficient throughput of heat.

Operation of the Stora Powder Steel Process makes it tempting to try making compound steels. One or both of the two sheets which form the box should then consist of, for instance, stainless steel. Tests made have shown, however, that the atmosphere during decarburization is too oxidizing, and because of that an oxide layer is formed on the surface of the stainless steel and this oxide hinders the welding together of the two steels. It might be possible to protect the surface of the stainless steel in such a way that it will not be oxidized, and that possibility is now being studied.

## Large scale operation

Test work with the Stora Powder Steel process has not been carried out in large scale operation. However, every separate operation of the process has been studied in full scale. This is true for the prerefining and the granulation of pig iron as well as decarburization and rolling of the powder. A possible method of operation in full production scale is shown in Fig. 7.

Instead of working with separately manufactured boxes, it is quite possible to make the process fully continuous. In such a process, the cover should be formed from a strip moving at the same speed as the conveyor; in this case only welds alongside the box are needed. The box with the powder would be one unit from charging the powder to the end of decarburization. As it is probably more suitable to have the rolling mill operate at a speed independent of the conveyor, the hot box should be cut in suitable lengths before going to the end zone of the furnace.

## General remarks

In a plant where steel production is based solely on the Stora Powder Steel process, only a blast furnace or cupola with prerefining and a rolling mill are needed. The heating furnace will, however, be somewhat larger and more complicated than normally. It is clear that great savings in capital cost and manhours per ton will be made in such a plant, but on top of that another item in the cost calculation is very favorable. The iron yield is much higher than in conventional steelmaking methods. In comparison to a normal steel plant, there is no iron loss in slag, smoke, sculls, ingot butts, or crops in the blooming mill. The iron yield of finished steel out of pig iron going from the blast furnace to a finished sheet bar will thus be 110 pct at a carbon content of 3.5 pct in the pig iron. For a normal steel plant this figure is 70 to 75 pct. The surface of the sheet bars is naturally good, as it consists of sheet produced in an earlier stage, so there is no need for surface conditioning.

It is quite possible to make heavy plate by doubling the bars in the rolling operation, provided that the furnace atmosphere can be kept strongly reducing and oxide-free surfaces can be obtained. Sheet bars tested weigh 70 kg, but a box 1 m wide, 10 m long, and 100 mm thick would weight 4 tons.

It is naturally difficult to arrive at a reliable production cost calculation at this stage of development of the process, but preliminary data show that the Stora Powder Steel should be one to two dollars per ton cheaper than ordinary steel. This is quite an important gain, which will surely stimulate further development work.

## References


[1] Bo Kalling and Ivar Rennerfelt: *Decarburization of granulated pig iron. The K.K. process, Journal*, Iron Steel Institute, 1939, II, pp. 137P-160P.

[2] G. Naeser, H. Steffe, and W. Scholz: Die Grundlagen des Roheisen-Zunder-Verfahrens zur Herstellung von Eisenpulver, *Stahl und Eisen*, 1949, vol. 68, pp. 346-353.

[3] H. Buchholtz: Die heutigen Verfahren zur Herstellung von Eisenpulver, ihre Rohstoffgrundlagen und Wirtschaftlichkeit, *Stahl und Eisen*, 1949, vol. 69, pp. 247-256.

[4] G. Naeser and F. Zirm: Walzen von Bandern aus Eisenpulver, *Stahl und Eisen*, 1950, vol. 70, pp. 995-1004.

[5] H. Franssen: Das Pulverwalzverfahren und seine wirtschaftlichen Aussichten. *Metall*, 1954, vol. 8, pp. 365-368.

[6] P. E. Cavanagh: Direct reduction yields variable density steels, *Iron Age*, 1952, vol. 169, pp. 63-68.

[7] E. W. Williams: The tensile strength of light steel. *The Canadian Mining and Metallurgical Bull.* 1957, vol. 60, pp. 89-95.

[8] Bo Kalling and F. Johansson: *Blast Furnace and Steel Plant*, Feb. 1957, vol. 45, pp. 200-203.

[9] T. Mortsell: Dry magnetic separator. Swedish Patent 158,672.

[10] Bo Kalling, C. Danielsson, and O. Dragge: Desulphurization of pig iron with pulverized lime. JOURNAL OF METALS, 1951, vol. 3, pp. 732-738.

[11] S. Eketorp: Desulphurizing with solid lime. *Blast Furnace and Steel Plant*, 1954, vol. 42, pp. 1159-1161, 1177.

by G. Meister and W. C. Lilliendahl

# PREPARATION OF URANIUM METAL BY FUSED SALT ELECTROLYSIS

*Uranium metal with a purity of about 99.9 pct was produced on a large scale by fused salt electrolysis with a material efficiency of about 90 pct. The material efficiency depends mainly on bath composition, electrolysis temperature, electrode smothering, and elutriation during washing of the powder.*

RESEARCH and development work on fused salt electrolysis carried on by the Westinghouse Lamp Div. Bloomfield, N. J., was done under the Manhattan District Corps of Engineers and later under the Atomic Energy Commission for the commercialization of uranium production for the first atomic pile at the University of Chicago in 1942.

From the conception of the atomic bomb project it was recognized that metals with impurity levels having little metallurgical significance would be required. Permissible impurity levels were based on neutron absorption. Of particular significance was boron, which could not be present in amounts exceeding 1 ppm.

The electrolytic method as developed in 1930 by Driggs and Lilliendahl,[1,2] and later improved, yielded uranium of very low boron and other deleterious impurity content. No other method was capable at that time of producing uranium metal of the required purity.[3] The low boron content of uranium produced by the electrolytic process resulted from the availability of the reactants which were low in boron content, and from the inherent elimination of boron in the fused salt bath.

Since the heart of any electrolytic process is the electrolysis cell, this paper will deal with the development of the original bath composition for the efficient production of uranium from a batch process to one of continuous operation. Emphasis also will be placed on other factors which will affect the material efficiency of the process.

With the laboratory cell the material efficiency of uranium powder recovery in the early electrolysis was relatively low, about 35 pct based on the ratio of uranium recovered to uranium added. This early process also had other defects. The electrolytic bath could not be used continuously. After three runs from a freshly charged crucible, the deposit showed a tendency to slip off the electrode as it was raised from the bath. This condition necessitated pouring the charge every fourth run and preparing a new bath. It was assumed at that time that this condition was caused by the increasing fluoride concentration with each addition of uranium salt, which affected the mobility of the uranium ions.

## Experimental

The electrolysis cells differed in size only. They were of the floating cathode type.

The laboratory cells were 2½ in. ID and 6 in. deep and operated at 30 amp and 5 volts. Production was about 150 g metal powder per 8 hr. The plant cells (5 units) were 9 in. ID x 21 in. deep and operated at 1800 amp at 12 volts. The total production unit was designed to produce 250 lb of uranium powder per 8 hr day.

Because of the tendency of uranium fines toward spontaneous combustion, material efficiencies were based only on the recovery of useful coarser metal which could be safely handled. The reported efficiencies are of particular significance only as related to the same group of experimental procedures.

At the start of the project no changes were contemplated until previous data could be definitely confirmed. Therefore, the first experiments were with the 50 pct $CaCl_2$-50 pct NaCl mixture. The material efficiency of uranium deposition as a function of the number of electrolyses is shown in Table I.

In Table I, the decrease in efficiency at 800°C with number of runs is apparent and confirmed the earlier data. Operating at 900°C enabled the number of runs to be doubled, but before pouring the charge the efficiency of recovery became poor. This test indicated that the improved efficiency might have been caused by an increase in the fluidity of the bath.

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TP 4604D. Manuscript, Mar. 5, 1956. New York Meeting, February 1956.



The Transactions papers appearing in JOURNAL OF METALS during 1957 will subsequently appear in AIME Transactions Volume 209, and may be permanently referenced to that volume.

Table I. Material Efficiencies with Continuous Use of 50 Pct $CaCl_2$-50 Pct NaCl Bath

| Run Nos. | Uranium Salt | Temperature, °C | Powder | Average Efficiency |
|---|---|---|---|---|
| 1 to 4 | $KUF_5$ | 800 | coarse | 60.5 |
| 5 to 7 | $KUF_5$ | 800 | coarse | 32.0 |
| 1 to 8 | $KUF_5$ | 900 | coarse | 60.0 |
| 9 to 12 | $KUF_5$ | 900 | coarse | 42.0 |

Table II. Material Efficiencies with Continuous Use of 80 Pct $CaCl_2$-20 Pct NaCl Bath

| Run Nos. | Uranium Salt | Temperature, °C | Powder | Average Efficiency |
|---|---|---|---|---|
| 1 to 4 | $KUF_5$ | 800 | coarse | 61.5 |
| 5 to 8 | $KUF_5$ | 800 | coarse | 63.0 |
| 9 to 12 | $KUF_5$ | 800 | coarse | 51.5 |

Table III. Material Efficiencies with Different Uranium Salts

| Uranium Salt | No. of Runs | Bath | Temperature, °C | Powder | Average Efficiency |
|---|---|---|---|---|---|
| $KUF_5$ | 3 | 80 pct $CaCl_2$-20 pct NaCl | 900 | coarse | 52 |
| $UF_4$ | 3 | 80 pct $CaCl_2$-20 pct NaCl | 900 | coarse | 75 |
| $UF_4$ + KF | 3 | 80 pct $CaCl_2$-20 pct NaCl | 900 | coarse | 51 |
| $UF_4$ | 41 | 80 pct $CaCl_2$-20 pct NaCl | 800 | coarse | 68.4 |
| $KUF_5$ | 36 | 80 pct $CaCl_2$-20 pct NaCl | 800 | coarse | 59.6 |

Table IV. Salt Consumption in Electrolytic Baths

| Original Bath Composition, Pct | | | | | |
|---|---|---|---|---|---|
| $CaCl_2$ | NaCl | Temperature, °C | Bath | Uranium Salt Used | Ratio of Salt Used to Metal Produced |
| 50 | 50 | 800 | 4 runs, discard bath | $KUF_5$ | 10 |
| 50 | 50 | 900 | 8 runs, discard bath | $KUF_5$ | 6 |
| 80 | 20 | 800 | 15 runs, discard bath | $KUF_5$ | 3.8 |
| 80 | 20 | 800 | continuous, dip and recharge | $KUF_5$ | 3.4 |
| 80 | 20 | 800 | continuous, dip and recharge | $UF_4$ | 3.0 |

Table V. Increase in Yield of Metal Powder with Salt Smothering

| Test | Salt Smother | Salt Used | Bath Temperature, °C | Powder | Average Yield, Pct |
|---|---|---|---|---|---|
| *A* | No | — | 900 | coarse only | 59 |
| *B* | Yes | NaCl | 900 | coarse only | 75 |
| *C* | Yes | $CaCl_2$ | 900 | coarse only | 65 |

Table VI. Yields of Metal Powder Obtained with the Aid of an Elutriator in Experimental Factory Production

| Test | Theoretical Yield, G | Metal Recovered, Coarse, G | Metal Recovered in Elutriator, Fine, G | Pct of Recovery, Coarse and Fine |
|---|---|---|---|---|
| *A* | 20,600 | 17,514 | 2,284 | 96 |
| *B* | 24,800 | 19,290 | 2,475 | 88 |
| *C* | 18,786 | 16,500 | 1,100 | 93.9 |
| *D* | 25,776 | 21,000 | 1,304 | 86.7 |

Table VII. Chemical Purity of Fused Uranium*

| Impurity | Lots Analyzed | High Ppm | Average Ppm |
|---|---|---|---|
| Boron | 30 | 1.05 | 0.61 |
| Iron | 10 | 260 | 162 |
| Chlorine | 12 | 10.1 | 4.4 |
| Nitrogen | 21 | 7.7 | 4.5 |
| Molybdenum | 20 | 100 | 32 |
| Copper | 10 | 20 | 16 |
| Lead | 10 | 35 | 22 |
| Nickel | 10 | 20 | 11 |
| Cobalt | 10 | 26 | 15 |
| Silver | 10 | 1 | 1 |
| Manganese | 10 | — | 7 |
| Chromium | 10 | — | 10 |
| Sodium | 10 | — | 10 |
| Cadmium | 10 | 0.3 | 0.1 |
| Titanium | 10 | 8 | 5 |
| Silicon | 10 | 50 | 33 |
| Sulfur | 10 | 350 | 310 |
| Hydrogen | 7 | 28 | 13 |
| Carbon | 7 | 1400 | 1120 |

* Total metallic impurities, 0.033 pct.

It therefore seemed logical to adjust the calcium chloride content of the bath between 50 and 100 pct, which might result in dissolving increasing amounts of calcium fluoride and reducing the viscous condition of the bath which was concurrent with poor operating efficiency. The idea was tested using a bath composition of 80 pct $CaCl_2$ and 20 pct NaCl.

In Table II, a marked increase in efficiency is noted over that experienced with the 50 pct $CaCl_2$-50 pct NaCl bath. The efficiency, however, begins to fall off after eight runs. This electrolyte became very viscous and unusable after ten or more runs. It seemed that the material efficiency always decreased considerably as the bath became more viscous, probably due to increased calcium fluoride concentration which was theorized as troublesome in the earlier work. To see if this explanation were true, several cooling curves were taken of different bath compositions. These cooling curves indicated that the viscous nature of the bath after several runs was actually caused by an increase in calcium fluoride concentration.

It was highly desirable, however, in the large scale operation contemplated, for a continuously operating bath to be found. The allowable fluoride concentration for a continuous run was estimated by calculation as between 20 and 30 pct $CaF_2$.

In addition to the problem of fluorides the potassium content of the bath appeared to have a marked effect on increasing the pyrophoric properties of the deposited powder. Continuous experimentation with baths containing $KUF_5$ indicated that $UF_4$ might be a superior salt to substitute for $KUF_5$. At the start of the project, this uranium salt ($UF_4$) was not available in quantities with sufficiently low boron content.[5] Later $UF_4$ was used in both the laboratory and plant operations. In Table III, the efficiencies of baths operating on $KUF_5$, $UF_4$, and $UF_4$ + KF are tabulated.

From Table III it is seen that the efficiencies for coarse powder are highest with the use of uranous fluoride ($UF_4$), indicating that potassium is an objectionable element because it produces excessive fines and therefore reduces the material efficiency.

The yield of coarse metal powders could be increased by recharging with more bath salts, thereby keeping the concentrations of $CaF_2$ and KCl low. In Table IV the ratio of salt used to metal produced is tabulated for the early batch type of operation and for the final continuously operated bath.

This tabulation shows that there is a marked decrease in salt consumption in the operation of the 50 pct $CaCl_2$-50 pct NaCl and the 80 pct $CaCl_2$-20 pct NaCl baths. Salt consumption is reduced further in the continuously operated bath because the fluoride concentration, which affects the viscosity, is kept low. The effect of temperature on salt consumption is noted in the 50 pct $CaCl_2$-50 pct NaCl bath.

Although the material efficiency had been increased over that of the early work on electrolysis, further improvements were always sought. It was noted that, as the electrode was removed from the bath of the production cell, there were always some signs of metal burning. The most successful procedure to overcome this difficulty was to smother the electrode by removing it from the hot electrolytic bath and immediately submerging it in fine dry sodium chloride contained in a can which was water-cooled. The average yield of powder in five test runs under the same conditions increased from 68 pct without salt cooling to 82 pct with salt smothering. Results of test runs on the production cell are given in Table V.

Dry sodium chloride was found best for quenching. This procedure also made the removal of the deposit easier. If the electrodes, after smothering of the deposit and while it was still hot and plastic, were removed with a twisting motion, the electrodes could be stripped of the deposit.

A further improvement in the yield of metal powder was finally made by recovering the fines by elutriation. The fine powder so recovered, if properly washed, was found to be as stable as the coarse powder, and gave good yields of fused metal. The total uranium recovered when using the elutriator is shown in Table VI.

It is seen from Table VI that, when the uranium fines were recovered by elutriation and included in the total powder recovered, then the material efficiency for these salt combinations averaged about 90 pct of the total uranium added. The residue, which was composed chiefly of uranium oxide, was collected as sludge and converted to uranium salts.

This experimental plant actually produced more than 60 tons of pure uranium by this process.[4,5]

## Purity of Product

It was indicated that the production of pure uranium was dependent upon the exclusion of many impurities. The electrolytic method was inherently able to act as a purification process prior to the actual deposition of metal at the cathode. Thus, at times, calcium chloride or other intermediates would show abnormally high boron concentrations. These could be reduced to a low order of magnitude by 1) allowing the fused bath to stand prior to electrolysis, and 2) deposition of impurities on an auxiliary *dummy* electrode followed by the substitution of another for the primary deposition.

Iron contamination of graphite crucibles was also a problem at times. As the crucible was the anode during the electrolysis, iron was readily dissolved into the bath and deposited with the uranium. It was found that the iron content of crucibles could be appreciably reduced by continued electrolysis.

Some idea of the purity obtained is shown in the compilation in Table VII, which represents a composite of 7.5 tons divided into 30 lots of 500 lb each.

## Conclusions

It was shown that uranium with a purity of about 99.9 pct could be produced on a large scale by fused salt electrolysis with a material efficiency of about 90 pct. Material efficiency depended on two operations, electrolysis of uranium salt and processing of uranium deposit. The main factors discussed which affected material efficiency were composition of bath, temperature of electrolysis, type of uranium salt electrolyzed, smothering of electrode, and recovery of fine uranium powder by elutriation during washing.

Over 60 tons of pure uranium were produced by this process. This high purity uranium, which was low in boron, was successfully used in the first atomic pile.


## Acknowledgments

The work and data reported in this paper resulted from a cooperative effort of members of the Research Staff of the Westinghouse Lamp Div. In addition to the authors the following personnel were particularly involved: J. W. Marden, D. W. Wroughton, R. Nagy, and N. C. Beese.


## References


[1] F. H. Driggs and W. C. Lilliendahl: *Industrial and Engineering Chemistry*, 1930, vol. 22, p. 516.

[2] F. H. Driggs and W. C. Lilliendahl: U. S. Patent No. 1,861,625, 1932.

[3] H. D. Smyth: *Atomic Energy for Military Purposes*, pp. 92-94. Princeton University Press, Princeton, 1946.

[4] W. C. Lilliendahl, D. Wroughton, R. Nagy, and J. W. Marden: U. S. Patent No. 2,690,421, 1954.

[5] G. Meister: *Metal Progress*, 1948, vol. 53, p. 515.



**Discussion** of this paper sent (2 copies) to AIME by Jan. 1, 1958 will appear in AIME *Transactions* Vol. 212, 1958, and in JOURNAL OF METALS, October 1958.


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Technical Note

# Electrical Conductivity of $PbO$-$B_2O_3$ Melts


by Wm. C. Phelps, Jr., and R. E. Grace

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ELECTRICAL conductivity of slags and glasses is of particular interest when viewed as an activated ionic flow process. The ionic conductivity, for example, has been found to obey the Rasch-

Hinrischen law as a function of temperature. That law may be stated as $K = A \exp(-Q/RT)$ where $K$ is the specific electrical conductivity, $A$ is a constant for each composition, and $Q$ is the energy of activation for conduction.

The specific electrical conductivities of molten boric oxide and of two molten boric oxide-lead oxide solutions were measured at temperatures from 650° to 850°C by an ac voltage drop method described elsewhere.[1] A two-terminal conductivity cell which consisted of two rigidly supported platinum electrodes dipping into a Vycor container was heated in a vertical tube resistance furnace. Melts were prepared by dewatering $H_3BO_3$ in graphite crucibles at 1100°C and then adding 2.4 and 4.0 mol pct PbO to dehydrated boric acid, $B_2O_3$. Samples of each melt were analyzed for PbO by the gravimetric sulfate method at the end of each run, and boric oxide was taken by difference.

Measurements of electrical conductivity and temperature were made as the melts were heated and cooled. The conductivity-temperature relationship was found to be identical for both heating and cooling. Plots of ln K vs $10^4/T$, shown in Figs. 1 and 2, consist of straight line portions which indicate a constant Q for each linear portion. Breaks in the curves of Fig. 1 correspond to the appearance of a second phase, according to the constitution diagram for the system $PbO$-$B_2O_3$.[2] In the single liquid range the pure $B_2O_3$, 2.4, and 4.0 mol pct PbO melts have $Q$ values of 30, 27, and 27 kcal per mol, respectively.

The specific conductivity of pure $B_2O_3$ was found to be the same order of magnitude as that obtained by Parks and Thomas,[3] while Shartsis et al.[4] found it to be greater by a factor of ten. Arndt and Gessler,[5] in earlier work, obtained intermediate values. Activation energies, $Q$, calculated from the latter two sources were 28 and 27 kcal per mol, respectively.

The activation energy for conduction of 27 kcal per mol in the lead oxide-boric oxide melts is similar to that calculated from the data of Shartsis et al.[4] on several alkali metal oxide-boric oxide melts, namely, about 25 kcal per mol at low alkali metal oxide concentration. This close correspondence of activation energies indicates a common modification mechanism in $B_2O_3$ networks modified by oxides containing univalent or divalent cations.

## References


[1] G. Pound, G. Derge, and G. Osuch: Electrochemical Studies of Non-Aqueous Melts. *AIME Trans.*, 1955, vol. 203, p. 481; JOURNAL OF METALS, March 1955.

[2] R. Geller and E. Bunting: The System PbO-$B_2O_3$. *Journal of Research* NBS, 1937, vol. 18, p. 585.

[3] S. Thomas and G. Parks: The Conductivities and Dielectric Constants of Glucose and $B_2O_3$ Glasses. *Journal of Physical Chemistry*, 1931, vol. 35, p. 2103.

[4] L. Shartsis, W. Capps, and S. Spinner: The Viscosity and Electrical Resistivity of Molten Alkali Borates. *Journal* Amer. Ceramic Soc., 1953, vol. 36, p. 319.

[5] K. Arndt and A. Gessler: Electrical Conductivity Measurements in Molten Salts. *Ztsch. für Electrochemie*, 1908, vol. 14, p. 662.


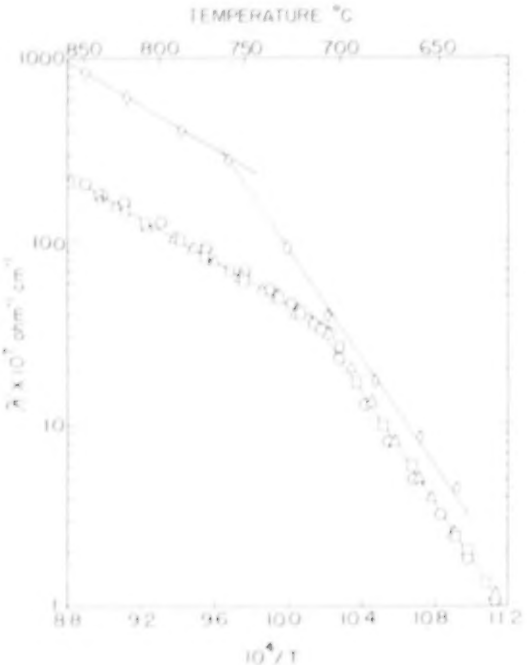


Fig. 1—Specific conductivity of lead oxide-boric oxide melts. Diamonds refer to 4.0 mol pct PbO, on cooling; squares, 2.4 mol pct PbO, first cooling run; triangles, second cooling run; and circles, heating run.

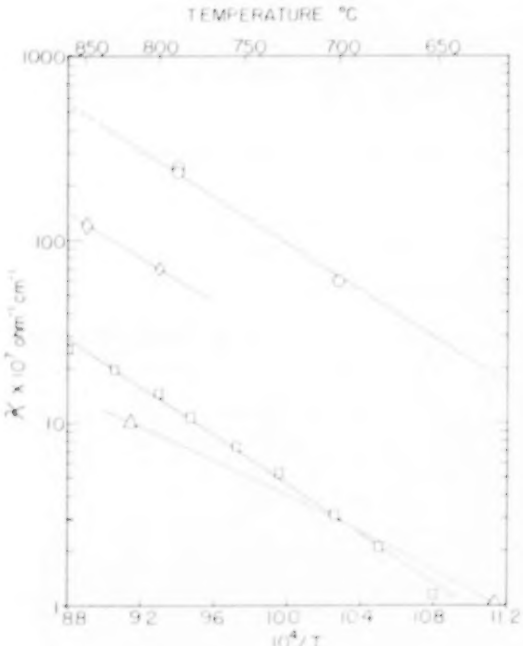


Fig. 2—Specific conductivity of boric oxide, $B_2O_3$. Circles refer to data of Shartsis, Capps, and Spinner;[4] triangles, Parks and Thomas,[3] diamonds, Arndt and Gessler,[5] and squares, this research.

by Joseph B. Story and John T. Clarke

# Electrical Conductivity of Fused Sodium Chloride-Calcium Chloride Mixtures

*A modification of the Kelvin bridge using an inductor was used to measure the conductivities of molten sodium chloride, calcium chloride, and mixtures thereof. A capillary-type four-lead fused quartz dipping cell was constructed. The effect of a small amount of potassium chloride on the conductivity of the melt was determined.*

IN the electrowinning of sodium and chlorine from sodium chloride in Downs cells, calcium chloride is added to the sodium chloride in an approximately equimolar amount to permit cell operation at a lower temperature. This lower temperature improves current efficiency and ease of operation, but decreases voltage efficiency by decreasing the electrical conductivity of the melt. A knowledge of the electrical conductivity of the Downs cell melt is necessary to the understanding of Downs cell operation, for the IR voltage drop across the melt is responsible for a significant part of the electrical power consumed by the cell.

The work of previous investigators on fused sodium chloride-calcium chloride mixtures was reviewed from the standpoint of consistency with the results of others on the conductivities of the pure constituents. The electrical conductivity of pure fused sodium chloride has been established with accuracy by Van Artsdalen and Yaffe,[1] by Edwards, Taylor, Russell, and Maranville,[2] and by Lee and Pearson.[3] It has also been studied by a number of other investigators.[4-9] The best values for calcium chloride are believed to be those of Lee and Pearson,[3] since the sodium chloride and potassium chloride conductivity values given by them check the best literature values. A number of other investigators have also reported values for calcium chloride.[3-6,10-14]

Electrical conductivity data for fused sodium chloride-calcium chloride mixtures have been reported by Sandonnini,[15] Vereshchetina and Luzhnaya,[16] Ryschkewitsch,[11] Barzakovskii,[6] and Alabyshev and Kulakovskaya.[10] Sandonnini reports no data at temperatures lower than 850°C. The conductivity values reported by Vereshchetina and Luzhnaya, by Ryschkewitsch, and by Barzakovskii for pure sodium chloride and for pure calcium chloride vary somewhat from the literature values believed to be best and the sodium chloride-calcium mixture data of these authors and of Alabyshev and Kulakovskaya (who give no data for the pure compounds) show significant variations. In view of these facts, it seemed that an investigation of the electrical conductivities of fused sodium chloride-calcium mixtures would be worthwhile.

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## Apparatus

**Bridge System**—The bridge used in this investigation is diagrammed in Fig. 1. In general, the elaborations of this bridge over the simple Wheatstone bridge were for the purposes of a) eliminating lead resistances or making them accurately measurable, and b) eliminating major capacitative and inductive effects or balancing them against each other.

Lead resistances in the lower arms of the bridge were kept as low as possible by making the leads short and of low resistance wire. This could not be done in the cell arm of the bridge because of the remoteness of the cell from the other bridge components and because of the high-resistance nickel or chromel wires used in the cell. Since maximum sensitivity is attained when the resistances of the four arms of the bridge are equal, 50-Ω resistors were used in the lower arms of the bridge when fused salt conductivities were being measured, and 1000-Ω resistors were used when the cell was being calibrated with normal aqueous KCl solution. The cell resistance was of the order of 50 ohms with fused salts and of the order of 1000 ohms with normal aqueous KCl solution. The resistors used were non-inductive and accurate to ±0.05 pct (General Radio Co. Types 500-C and 500-H).

The lead resistance between point $A$ in the cell and point $E$ at the measuring resistor was eliminated by using the Kelvin bridge principle; that is, the voltage drop across the lead from point $A$ to point $E$ was divided between the cell arm of the bridge and the measuring arm of the bridge in proportion to the resistances in the lower arms of the bridge.

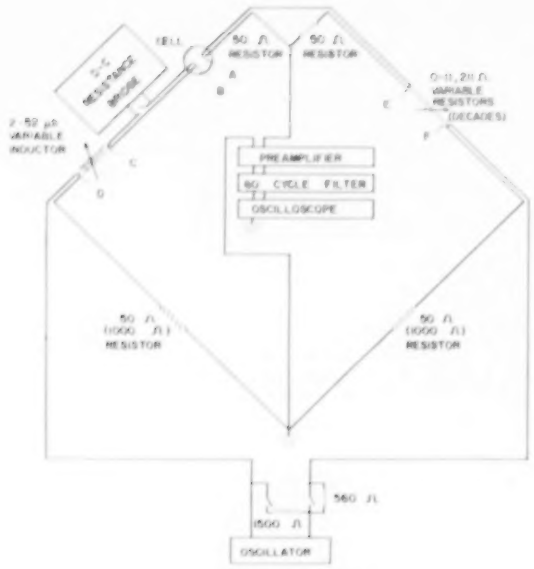


Fig. 1—Diagram of the bridge.

The 50-Ω resistors used to divide the voltage drop were of the same type as used for the lower arms of the bridge.

A double lead was used between point *B* in the cell and point *C* on the inductor, with the resistances of the individual leads matched against each other. One of the leads was provided with a switch across which a dc resistance bridge was connected (Rubicon Portable Wheatstone Bridge No. 1352). This arrangement permitted a determination of the parallel resistance of the leads at each cell temperature by a series resistance measurement.

The measuring resistors used in the upper right arms of the bridge were a 3-decade 0-11,100 (in steps of 10Ω) resistor (General Radio Co. Type 1432-C) in series with a 3-decade 0-111.0 (in steps of 0.1Ω) resistor (General Radio Co. Type 670-F). These resistors had a small inductive effect.

The fused salt cell had a very large capacitance (of the order of 100 μfarads) which varied widely with temperature. In order to make the bridge balance properly, the cell arm of the bridge was made to behave as a pure resistance, or only differently enough therefrom to compensate for the small inductance in the measuring arm. This was done by using a variable inductor (2 to 52 μhenries General Radio Co. Type 107-J) in series with the cell. The use of a variable coupled inductor to compensate for cell capacitance was suggested by Wenner[4] and used by Edwards, Taylor, Russell, and Maranville.[5] In the latter use, the coupling was between one oscillator lead and the bridge arm corresponded to the lower right arm of the bridge in Fig. 1. During the development of the apparatus, a test was made of the effect of frequency upon cell resistance. At this time measurements were made only to 0.3 pct. Within this limit, the resistance was independent of frequency from 1,000 to 40,000 cps. Frequencies less than 1,000 cps were not tested.

A DuMont Type 304-A oscilloscope was used. The 60-cycle filter was a Kay Lab Model 503A. The single-stage amplifier (gain = 25) was constructed which increased the sensitivity of the bridge balance to 1 part in 10,000. However, satisfactory data could have been obtained without using the amplifier.

The oscillator was a General Radio Co. Type 1302-A. A switching arrangement was made whereby a 560-Ω resistor could be connected in series with one of the oscillator leads, or a 1500-Ω resistor in parallel across the leads. This was done to provide a load of approximately 600 ohms for the oscillator for either fused salt or standardization measurements.

**Furnace**—Details of the cell assembly are shown in Figs. 2 and 3. The furnace was tubular, 16 in. long with a 3-in. bore (L. H. Marshall Co., Columbus, Ohio). This furnace and its controller (of the same manufacture) maintained the sample at constant temperature. Under the best conditions of thermal equilibrium, there was no measurable temperature change over a period of 15 min. Normally, however, there was a slight temperature variation. The average set of measurements was taken over a period of 13 min, during which time the temperature changed 0.4°C. The close fit of the equipment prevented a determination of the vertical temperature gradient in the furnace under operating conditions, but such a measurement of less shielded arrangement showed a zone of at least 4 in. in the middle of the furnace which had a total temperature

Table I. Electrical Conductivity of Fused Sodium Chloride—Calcium Chloride Mixtures

| Mol Pct CaCl$_2$ | Temperature, °C | Conductivity, Ohm$^{-1}$ Cm$^{-1}$ |
|---|---|---|
| 0 | 900.4 | 3.87$_7$ |
| | 875.1 | 3.82$_0$ |
| | 856.4 | 3.77$_2$ |
| | 838.1 | 3.72$_4$ |
| | 810.2 | 3.64$_5$ |
| | 897.3 | 3.87$_8$ |
| 11.5 | 806.5 | 3.09$_5$ |
| | 781.1 | 3.03$_2$ |
| 26.4 | 810.8 | 2.60$_8$ |
| | 756.4 | 2.41$_2$ |
| | 704.8 | 2.21$_2$ |
| 48.2 | 807.0 | 2.25$_8$ |
| | 756.2 | 2.05$_8$ |
| | 709.1 | 1.86$_4$ |
| | 647.2 | 1.59$_2$ |
| | 595.8 | 1.36$_7$ |
| | 571.4 | 1.25$_7$ |
| | 555.8 | 1.17$_7$ |
| | 570.4 | 1.24$_6$ |
| 68.7 | 691.8 | 1.63$_8$ |
| | 746.8 | 1.87$_2$ |
| | 799.2 | 2.08$_8$ |
| 100 | 802.3 | 2.12$_2$ |
| | 851.3 | 2.34$_6$ |

Table II. Electrical Conductivity of the Fused Ternary System*

| Temperature, °C | Conductivity, Ohm$^{-1}$ Cm$^{-1}$ |
|---|---|
| 570.3 | 1.26$_5$ |
| 597.0 | 1.32$_4$ |

* 50.7 mol pct sodium chloride, 48.3 mol pct calcium chloride, and 1.0 mol pct potassium chloride.

Table III. Electrical Conductivity of the Fused Ternary System*

| Temperature, °C | Conductivity, Ohm$^{-1}$ Cm$^{-1}$ |
|---|---|
| 597.4 | 1.38$_7$ |
| 570.4 | 1.25$_6$ |
| 559.4 | 1.20$_9$ |

* 55.4 mol pct sodium chloride, 43.7 mol pct calcium chloride, and 0.88 mol pct barium chloride.

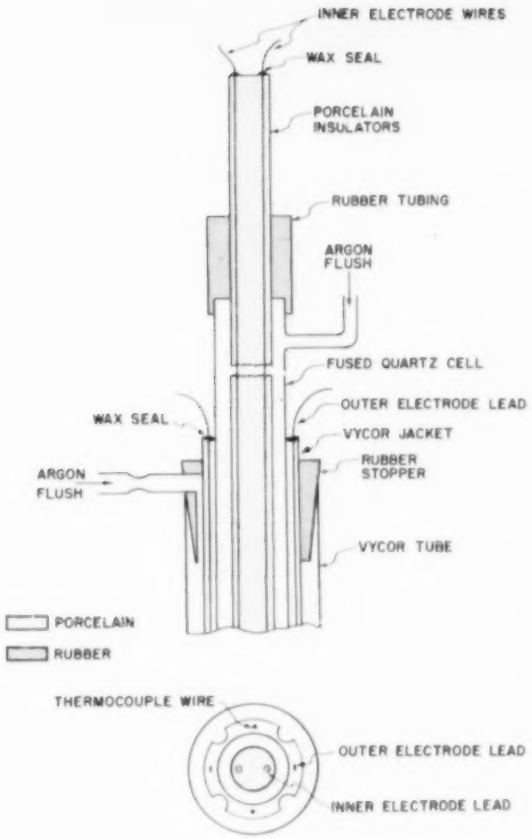


Fig. 2—Upper portion of cell assembly.

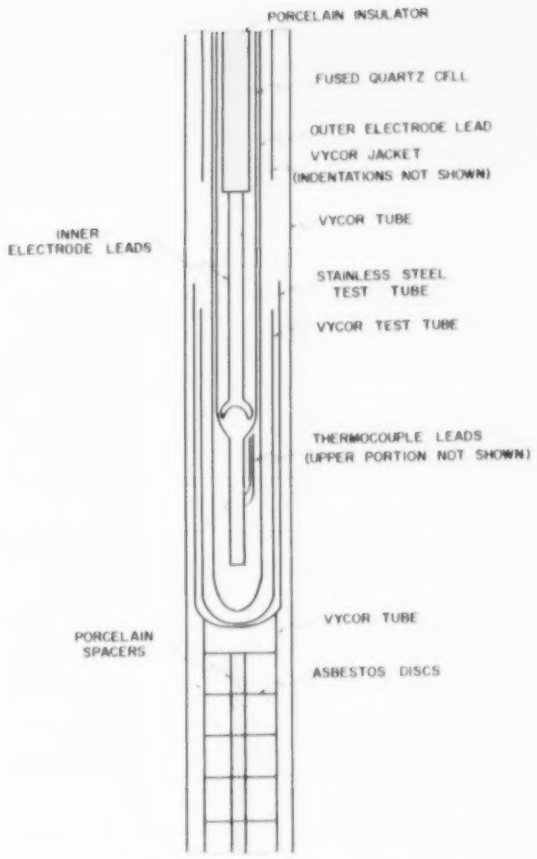


Fig. 3—Lower portion of cell assembly.

gradient of 1°C. The sample itself served as a constant temperature bath for the capillary. The cell assembly was inside a 30-mm Vycor tube 36 in. long. The space between the tube and furnace was partitioned by annular stainless steel plates, i.e., rings perpendicular to the tube, spaced 1 in. apart by porcelain thermocouple insulators. This was done to simplify temperature control. The cell came into the furnace through the top of the Vycor tube, and the sample through the bottom. This permitted measurements on a series of samples without removing the cell from the furnace.

**Conductivity Cell**—A high-resistance dipping type cell was used. It was constructed from a fused quartz microcombustion tube (Sargent Co. S-21770). The tube (exclusive of tip) was 525 mm long, 11.25 mm OD, and 8 mm ID; the tip was 30 to 35 mm long, 3.25 mm OD, and 1.5 to 2 mm ID. The resistance measured was that of the material in the capillary tip. One electrode was inside the combustion tube; it consisted of a loop of 0.040-in. nickel wire arched to prevent its approaching the capillary too closely. The ends of the wire were the leads, and were separated in the cell by porcelain thermocouple insulation. The other electrode was another loop on the outside of the cell. In early measurements this was of the same nickel wire as used for the inner electrode, but it was found that, even with an argon flush, enough oxygen entered the furnace during sample changes to embrittle the nickel. In later measurements a chromel strip was used; this strip was held in place by a 17-mm Vycor tube concentric with the cell. Into this Vycor jacket four rows of indentations were impressed. This made four passages between the cell and the jacket. Two, on opposite sides, were used for the outer electrode leads, and the other two were used for thermocouple wires. The tip of the thermocouple (chromel-alumel) was placed against the capillary at its middle. The temperature measurement was made with a precision potentiometer (Leeds and Northrup No. 8662).

The sample was contained in an 18-mm Vycor test tube 3½ in. long. This test tube was placed inside a larger test tube for support and safety. In the early measurements, the larger tube was a 25-mm Vycor test tube 4 in. long; a silver foil cylinder was placed between the test tubes to shield the thermocouple and capillary from furnace radiation. Because of a tendency of the larger Vycor test tube to stick inside the outer 30-mm Vycor tube, a 25-mm stainless steel test tube 3¾ in. long was later substituted. The sample tubes were pushed upward to the cell by a length of 22 or 25-mm Vycor tubing. Radiation and convection losses through this tube were minimized by stacking the tube with asbestos disks separated by 1-in. thermocouple insulators.

The equipment was used at temperatures as high as 1035°C.

## Procedures

The cell was calibrated at room temperature with 1.000 N aqueous potassium chloride solution made up according to Lange's *Handbook of Chemistry*, 6th Ed., p. 1389, and using the conductivity values given therein. During the calibration the inductor was shorted out and the frequency and the measuring resistors were adjusted until the sharpest balance of the bridge was obtained. At this point the capacitance of the cell should be most nearly balanced by the minor capacitative and inductive effects of the upper arms of the bridge, especially the small inductive effect of the measuring resistors. This balance point occurred at 1250 to 1650 cps in the early cells in which a nickel wire outer electrode was used, and at 850 cps in the later cells in which a chromel strip outer electrode was used. The sensitivity of the bridge was decreased by increasing or decreasing the frequency from these values, but the balance point was changed very little.

The thermocouple was calibrated at the melting point of sodium chloride (800.4°C).

The lead resistance between point $B$ in the cell and point $C$ on the inductor was determined at each cell temperature by measuring the series resistance of the leads (switch open). The switch was closed during the conductivity measurement, so that the leads between $B$ and $C$ were in parallel. The parallel resistance was one fourth of the series resistance. The dc resistance of the inductor was known. The cell resistance was found by subtracting the inductor resistance and the parallel lead resistance from the measured resistance of the cell arm of the bridge.

$$R_{ss} = R_{sb} - R_{sc} - R_{cb}.$$

In measuring fused salt conductivities, the oscillator frequency was set at 5000 cps and the variable inductor and variable resistors were adjusted until the wave height as seen on the oscilloscope was a minimum. It was possible to estimate the resistance to hundreths of an ohm by the changes of wave height on either side of the balance point. The voltage across the bridge was approximately 1 volt. No appreciable change in conductivity was observed on allowing samples to stand overnight in the cell, or upon approaching the temperature of measurement from higher or lower temperatures.

Between different samples, a rinse of the fused salt to be studied was used.

The salt mixtures were made up of reagent grade materials. These salt mixtures were melted and bubbled with HCl for ½ hr to decrease the calcium oxide to <0.1 pct. They were then cooled and pulverized in a dry-box. The composition of the mixtures was determined by chemical analysis.

## Results

The experimental data on the conductivities of sodium chloride, calcium chloride, and mixtures thereof are presented in Table I. Data showing the conductivities of sodium chloride-calcium chloride mixtures containing small amounts of the minor Downs cell melt constituents potassium chloride and barium chloride are given in Tables II and III. Each value presented in the tables represents the average of a number of readings taken at the given condition.

The effect of potassium chloride is shown more clearly in Table IV. For convenience, the ternary melt is considered as being derived from a binary melt by the substitution of a portion of the sodium chloride by an equimolar amount of potassium chloride. The conductivity of the ternary melt at 570°C is compared with that of the corresponding binary mixture. The effect of substituting 1 mol pct potassium chloride for sodium chloride is to lower the conductivity by 3 pct.

The data of Table III were taken with the intention of determining the effect of small amounts of barium chloride on the conductivity of the Downs cell mixture. However, the composition of the sample deviated enough from the intended composition so that a satisfactory comparison cannot be made. These data may be used to advantage, however, to provide a good estimate of the conductivity of an additional sodium chloride-calcium chloride mixture, Table V. Such data are needed for drawing the slopes of the curves in the low-temperature region of Fig. 5. The estimate was based on the Alabyshev and Kulakovskaya[18] data on the effect of small amounts of barium chloride on the conduc-

Table IV. Effect of Small Amounts of Potassium Chloride Upon the Conductivity of the Downs Cell Mixture at 570°C

| Composition, Mol Pct | | | |
|---|---|---|---|
| NaCl | $CaCl_2$ | KCl | Conductivity,* Ohm⁻¹ Cm⁻¹ |
| 51.7 | 48.3 | | 1.24 |
| 50.7 | 48.3 | 1.0 | 1.19$_6$ |

* Values were obtained graphically from the data of Tables I and II.

Table V. Estimate of the Electrical Conductivity of the Fused Sodium Chloride-Calcium Chloride Mixture*

| Temperature, °C | Conductivity, Ohm⁻¹ Cm⁻¹ |
|---|---|
| 597$_8$ | 1.39$_7$ |
| 570$_4$ | 1.26$_5$ |
| 559$_6$ | 1.21$_9$ |

* 55.9 mol pct sodium chloride and 44.1 mol pct calcium chloride.

Table VI. Comparison of Best Literature Values for the Conductivities of Pure Sodium Chloride and Pure Calcium Chloride with the Corresponding Values of the Investigators of Sodium Chloride-Calcium Chloride Mixture Conductivities

| | Conductivity, k, Ohm⁻¹ Cm⁻¹ | | | |
|---|---|---|---|---|
| Material | 800°C | 850°C | 900°C | Investigator |
| NaCl | | 3.739* | 3.881* | Van Artsdalen & Yaffe |
| | | 3.75$_2$ | 3.90$_6$ | Edwards et al. |
| | | 3.77 | 3.91 | Lee & Pearson |
| | | 3.75$_6$ | 3.87$_7$ | This study† |
| | | 3.66* | | Vereshchetina & Luzhnaya† |
| | | 3.42* | 3.61* | Ryschkewitsch† |
| | | 3.68* | 3.79 | Barzakovskii† |
| KCl | 2.237* | 2.359* | 2.466* | Van Artsdalen & Yaffe |
| | 2.24$_8$ | 2.36$_7$ | 2.46$_7$ | Edwards et al. |
| | 2.24 | 2.36 | 2.48 | Lee & Pearson |
| $CaCl_2$ | 2.12 | 2.34 | | Lee & Pearson |
| | 2.11$_5$ | 2.33$_9$ | | This study† |
| | 2.091 | 2.32* | | Vereshchetina & Luzhnaya† |
| | 2.13* | 2.38* | | Ryschkewitsch† |
| | 2.02 | 2.17* | | Barzakovskii† |

* Value was obtained by plotting literature data or using equation given.

† Investigators of sodium chloride-calcium chloride mixture conductivities (<800°C).

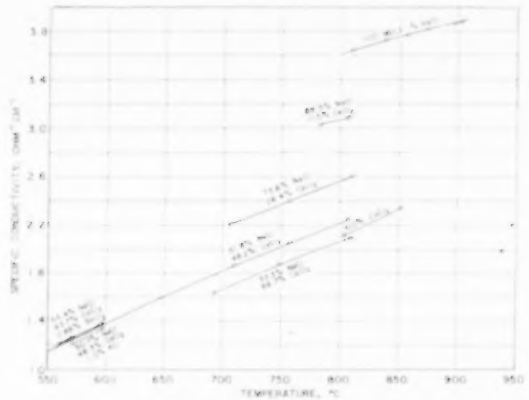

Fig. 4—Conductivities of fused sodium chloride-calcium chloride mixtures as a function of temperature.

tivity of the Downs cell melt. The effect of adding barium chloride to the Downs cell melt until the melt contains 0.88 mol pct barium chloride is to lower the conductivity by about 0.75 pct (between 550° and 600°C).

## Discussion

One probable source of error is the calcium oxide impurity in the calcium chloride. The calcium oxide reacts with the silica of the apparatus to form calcium orthosilicate $Ca_2SiO_4$.[14] The oxygen which entered the apparatus during sample changes probably did not cause an appreciable increase in the calcium orthosilicate content of the melt through its reaction with the Vycor test tube according to the equation

$$SiO_2 + 2CaCl_2 + 2O_2 \rightarrow Ca_2SiO_4 + 2Cl_2$$

since the oxygen is largely removed by flushing before the sample reaches reaction temperature. The calcium orthosilicate formed on the outside of the conductivity cell by the above reaction would not be expected to enter the measuring capillary during immersion. At any rate, the total attack on the conductivity cell was small. Additional hydrolysis of the calcium chloride by the atmospheric water vapor entering with the oxygen is probably very small.

Arndt and Loewenstein[14] have made a study of the effect of calcium orthosilicate upon the conductivity of calcium chloride. The equation for the conductivity of calcium chloride at 850°C is given as

$$k = 2.27 - 0.033x - 0.030y$$

where $k$ equals the specific conductivity of calcium chloride containing calcium orthosilicate and calcium oxide (ohm$^{-1}$ cm$^{-1}$); $x$ equals the percentage of calcium orthosilicate in the calcium chloride; and $y$ equals the percentage of calcium oxide in the calcium chloride. From this equation it can be seen that 0.10 pct calcium oxide converted to calcium orthosilicate (0.15 pct) lowers the conductivity by 0.005 ohm$^{-1}$ cm$^{-1}$ (0.2 pct).

Table VI compares the conductivity values of pure sodium chloride and pure calcium chloride as reported by investigators of sodium chloride-calcium chloride mixture conductivities (<800°C) with the literature values which are believed to be best. The selection of the best literature values for sodium chloride is not difficult, for there are three recent

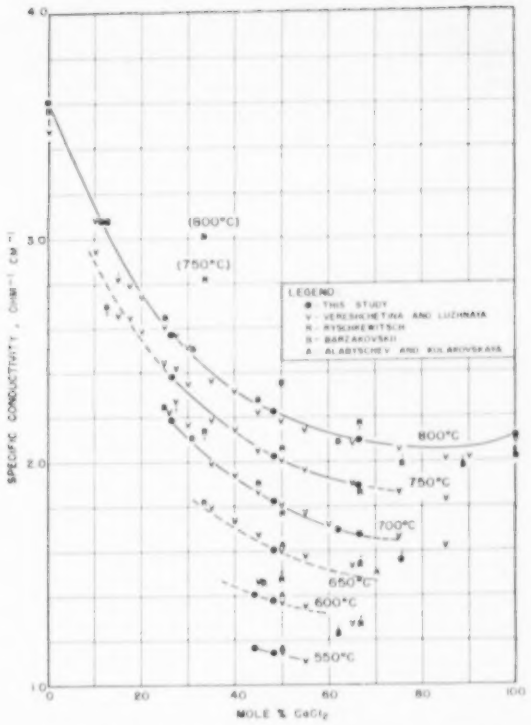


Fig. 5—Conductivities of fused sodium chloride-calcium chloride mixtures as a function of composition.

studies which agree closely (Van Artsdalen and Yaffe,[1] Edwards et al.,[2] and Lee and Pearson[3]), while the other values scatter from them. The potassium chloride data of these investigators also agree closely. Only one of these three studies (Lee and Pearson) reports calcium chloride values. The earlier calcium chloride data appear to be less trustworthy, for they are reported together with sodium chloride and potassium chloride data which do not check the best literature values. It is true, however, that the calcium chloride data of Mantzell[16] do check those of Lee and Pearson fairly well.

Inspection of the data of Table VI shows that the pure sodium chloride and pure calcium chloride conductivity values of this study check the best literature values well, while those of Vereshchetina and Luzhnaya, of Barzakovskii, and of Ryschkewitsch vary from these. This tends to give greater confidence in the mixture conductivities of this study than in those of the earlier investigators.

Fig. 4 represents the experimental data of this study. Values taken from this plot at 50°C temperature intervals are shown in Fig. 5, together with corresponding values from the studies of the earlier investigators.

Activation energies for electrical conductivity were calculated by the equation

$$\Lambda = A \exp\left(\frac{\Delta H}{RT}\right)$$

where $\Lambda$ is the equivalent conductivity, $A$ is a constant, $\Delta H$ is the activation energy of the conduction process, and $T$ is °K.

The average activation energies of pure sodium chloride and pure calcium chloride in the range 800° to 850°C were calculated to be 2.7 kcal per g

mol and 5.5 kcal per g mol, respectively. These check the corresponding sodium chloride value (2.8 kcal per g mol) of Van Artsdalen and Yaffe[1] and the corresponding calcium chloride values (5.5 and 5.3 kcal per g mol) calculated from the data of Lee and Pearson[3] and Vereshchetina and Luzhnaya.[16]

The energies of activation of sodium chloride-calcium chloride mixtures appear to be within 0.6 kcal per g mol of the values which would be expected on the basis of a linear mol pct-activation energy relation. The data are not sufficient for a more precise statement of the variation of activation energy with composition. The molar volumes of sodium chloride-calcium chloride mixtures vary linearly with molar composition, within the probable accuracy of the Vereshchetina and Luzhnaya[16] and Fuseya and Ouchi[15] density data.

## Summary

A detailed description has been given of an apparatus satisfactory for measuring fused salt conductivities. Accurate electrical conductivity data for fused mixtures of sodium chloride and calcium chloride have been presented. Data showing the effect of a small amount of potassium chloride on the electrical conductivity of a sodium chloride-calcium chloride mixture have been given.

## References

[1] E. R. Van Artsdalen and I. S. Yaffe: *Journal of Physical Chemistry*, 1955, vol. 59, p. 118-127.
[2] J. D. Edwards, C. S. Taylor, A. S. Russell, and L. F. Maranville: *Journal* Electrochemical Soc., 1952, vol. 99, pp. 527-535.
[3] E. K. Lee and E. P. Pearson: *Trans.* Electrochemical Soc., 1945, vol. 88, pp. 171-183.
[4] K. Arndt and A. Gessler: *Ztsch. für Elektrochemie*, 1908, vol. 14, pp. 662-665.
[5] V. P. Barzakovskii: *Journal of Applied Chemistry* USSR, 1940, vol. 13, pp. 1117-1118.
[6] V. P. Barzakovskii: *Bulletin* Academy of Sciences, USSR, 1940, pp. 825-831.
[7] W. Blitz and W. Klemm: *Ztsch. für Physikalische Chemie*, 1924, vol. 110, pp. 318-342.
[8] W. Blitz and W. Klemm: *Ztsch. für Anorganische Chemie*, 1926, vol. 152, pp. 267-294.
[9] P. W. Huber, E. V. Potter, and H. W. St. Clair: *Report of Investigation No. 4858*. U. S. Bureau of Mines. Washington, D. C., 1952.
[10] E. Mantzell: *Ztsch. für Elektrochemie*, 1943, vol. 49, pp. 283-287.
[11] E. Ryschkewitsch: *Ztsch. für Elektrochemie*, 1933, vol. 39, No. 7b, pp. 531-537.
[12] C. Sandonnini: *Gazzetta chimica italiana*, 1920, vol. 50, No. I, pp. 289-321.
[13] I. P. Vereshchetina and N. P. Luzhnaya: *Izvestiya Sektora Fiziko-Khimicheskogo Analiza* Institut Obshchei i Neorganicheskoi Khimii Akademiya Nauk USSR, 1954, vol. 25, pp. 188-207.
[14] K. Arndt and W. Loewenstein: *Ztsch. für Elektrochemie*, 1909, vol. 15, pp. 784-790.
[15] A. F. Alabyshev and N. Ya. Kulakovskaya: *Trudy Leningradskogo Tekhnologicheskogo Instituta im Leningrad. Soveta*, 1946, No. 12, pp. 152-164.
[16] F. Wenner: *Bulletin* Bureau of Standards, 1912, vol. 8, p. 559.
[17] H. Bloom and E. Heymann: *Proceedings* Royal Soc., London, 1947, vol. A188, pp. 392-414.
[18] G. Fuseya and K. Ouchi: *Journal* Electrochemical Soc., Japan, 1949, vol. 17, p. 254.

**Discussion** of this paper sent (2 copies) to AIME by Dec. 1, 1957 will appear in AIME *Transactions* Vol. 212, 1958, and in JOURNAL OF METALS, October 1958.

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by M. Bourgon, G. Derge, and G. M. Pound

# CONDUCTIVITY AND SULFUR ACTIVITY IN LIQUID COPPER SULFIDE

*The conductivity of liquid copper sulfide has been measured as a function of the mole fraction of sulfur in the melt at three temperatures: 1170°, 1250°, and 1300°C. The results show that a) the conductivity of copper-rich $Cu_2S$ is independent of the sulfur pressure in the furnace, and b) the conductivity of sulfur-rich copper sulfide increases rapidly with sulfur pressure. Assuming that the band theory is applicable to liquids leads to the conclusion that copper-rich copper sulfide is an intrinsic semiconductor, in which case electrons act as carriers. The activation energy for conduction in this case has been calculated to be 0.7 ev. On the other hand, sulfur-rich copper sulfide behaves as a p-type semiconductor, positive holes being responsible for conduction.*

IN order to elucidate the structure of liquid copper(I) sulfide, Derge, Pound, and Osuch[1] have studied the electrical conductivity of this compound as a function of temperature. Their results showed that the conductivity is rather high, of the order of 100 ohm$^{-1}$ cm$^{-1}$, and that the temperature coefficient of conductivity is positive. This high conductivity seemed to indicate electronic rather than ionic conduction. This conclusion was checked further by Derge, Pound, and Yang,[2] who measured the current efficiencies of copper sulfide melts at various temperatures. In all cases, the current efficiency was found to be nil, indicating the absence of appreciable ionic contribution to the conduction in

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TP 4627D. Manuscript, Feb. 6, 1957. New Orleans Meeting, February, 1957.

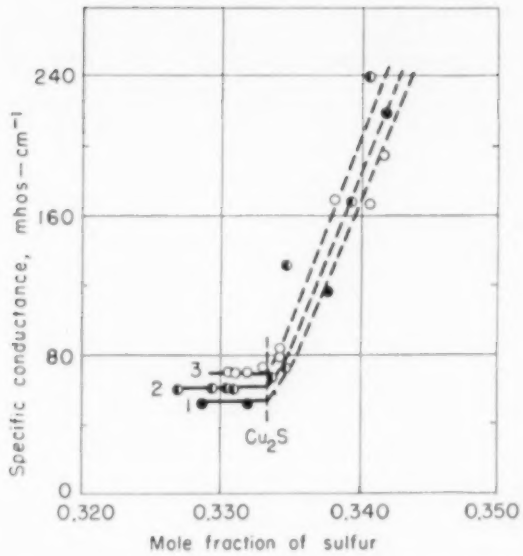


Fig. 1—Variation of the specific conductance of liquid copper sulfide as a function of the mole fraction of sulfur in the melt at three temperatures: 1170°, curve 1; 1250°, curve 2; and 1300°C, curve 3.

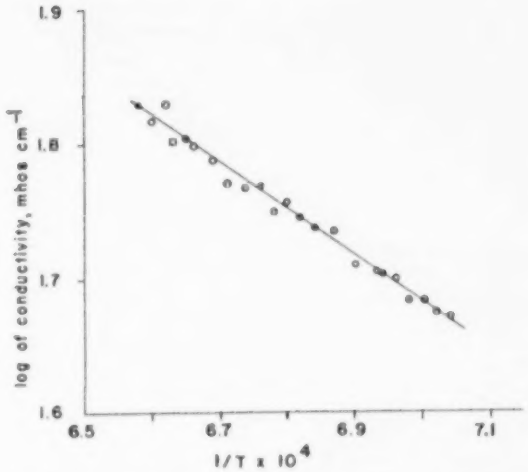


Fig. 2—Plot of the log of the specific conductance of liquid copper sulfide as a function of 1/T for copper-saturated melts.

the liquid. The behavior of liquid $Cu_2S$ is very similar to that encountered in solid semiconductors.

A few cases of liquid semiconduction have been reported. Chipman, Tomlinson, and Inouye[4] have studied the electrical conductivity of molten FeO and report a high specific conductance, of the order of 200 $ohm^{-1}$ $cm^{-1}$, and a positive temperature coefficient. They interpret these results in terms of $p$-type semiconduction in the liquid by analogy to the situation in solid FeO. Henkels[5] measured the conductivity of pure liquid selenium and concluded that this element was an ideal semiconductor in the range 200° to 500°C. Johnson,[3] using the results obtained by Epstein and Fritzsche,[6,7] concluded that liquid tellurium exhibited semiconduction which changed to metallic conduction at higher temperatures.

Copper sulfide with excess sulfur compared to $Cu_2S$ has been shown to be a $p$-type semiconductor in the solid state,[8-10] i.e., it conducts by means of positive holes instead of by electrons. A consequence of this is that the conductivity of this compound increases as the sulfur pressure is increased over it. This behavior is linked directly to the variation of the sulfur concentration in the solid as a primary function of sulfur pressure. Schuhmann and Moles[11] investigated the compositions of liquid copper sulfides as a function of sulfur pressure, and found that the latter was very sensitive to composition, especially as the sulfur contents were increased beyond $Cu_2S$. At 1150°C, the sulfur pressure $p_{S_2}$ was found to be $4.6 \times 10^{-7}$ atm for a copper-saturated melt, $9.4 \times 10^{-6}$ atm for stoichiometric $Cu_2S$ (20.14 pct S), and 0.14 atm for a 21.5 pct S melt. The corresponding figures at 1250° were $2.4 \times 10^{-6}$, $4.6 \times 10^{-5}$, and 0.23 atm, respectively, and at 1350°C were $10^{-4}$, $1.8 \times 10^{-4}$, and 0.35 atm, respectively. The large increase in the sulfur pressure for slight excess of sulfur above stoichiometric composition accounts for the well-known fact that artificial preparations of copper sulfide involving melting in open containers always give products close to $Cu_2S$ in composition.

Previous measurements of the electrical conductivity of liquid copper sulfide have been made in open containers under inert gas atmospheres, and it was expected that in all cases the melt would be copper-rich or very close to $Cu_2S$ in composition. Therefore, it was planned to investigate the conductivity of liquid copper sulfide as a function of sulfur pressure in order to obtain data for sulfur-rich melts. The results obtained would give more insight as to the mode of conduction in liquid copper sulfide.

The sulfur pressure can be varied over copper sulfide melts by circulating mixtures of hydrogen sulfide and hydrogen in the furnace. The pertinent reaction is

$$Cu_2S + H_2 \rightleftarrows 2Cu + H_2S$$

the $p_{H_2S}/p_{H_2}$ ratio being related to the sulfur pressure by means of the relation[10]

$$\log p_{S_2} = 2 \log \frac{p_{H_2S}}{p_{H_2}} - \frac{9665}{T} + 5.342.$$

The general technique adopted in this work was to bubble $H_2$-$H_2S$ mixtures of known composition into the liquid copper sulfide in order to vary the sulfur activity in the melt and to study the variation of electrical conductivity as a function of sulfur activity.

## Experimental Methods

The experimental procedure followed in this work was essentially the one used by Schuhmann and Moles.[11] Mixtures of hydrogen and hydrogen sulfide were bubbled into the molten copper sulfide until equilibrium was established, at which point the electrical conductivity was measured. The above authors used as criterion of equilibrium the equality of composition of the ingoing and outgoing gas mixtures. In this work, the reaction was followed by conductivity measurements and a constant value of the latter was taken to indicate an equilibrium position. This method proved to be faster in that it did not necessitate the furnace proper being in equilibrium with the gas mixture. Samples of the

melt were taken at each conductivity determination to obtain the composition of the copper sulfide.

**Furnace**—The furnace used was a Lindbergh type CF-2 with Globar elements, capable of reaching 1400°C. This is a horizontal model but, for this work, was turned on its side and used as a vertical furnace. The furnace protection tube was a McDanel Zircotube (zirconium silicate) 2¼ in. ID x 30 in. with ⅛ in. wall, open at both ends. This material proved to be very efficient under hydrogen sulfide atmospheres. The lower end of this tube was closed by a steel plate and rubber gasket. A ¼ in. copper tube soldered to this plate permitted introduction of argon to flush the furnace when necessary. The upper end of the furnace tube was closed by a water-cooled steel head and rubber gasket with sufficient openings to permit introduction of the thermocouple protection tube, the gas inlet tube, the gas outlet tube, and the electrodes. The furnace temperature was controlled by a Pt—Pt-10 pct Rh thermocouple connected to a six-point Celectray controller. A similar calibrated thermocouple was used to determine the temperature of the melt under study.

Inside the furnace, the melt was contained in a crucible 2 in. OD x 3 in. high with a 1/16 in. wall made of pure recrystallized alumina (Triangle RR ware, Morganite Corp.) which was supported by an Alundum tube and surmounted by three radiation shields made of K-30 brick. These shields were covered with a layer of alumina cement and drilled at various places to permit passage of the different tubes. Good temperature control was obtained with this arrangement.

**Atmosphere Control**—The $H_2/H_2S$ mixtures were conveniently prepared by means of two calibrated flowmeters, with capillary resistances, respectively connected to hydrogen and hydrogen sulfide cylinders. The metered gases were led through a glass-bead-filled chamber to insure proper mixing, and then through a third flowmeter before entering the furnace by way of a porcelain tube which dipped into the melt. The consequent bubbling of the gas mixture in the melt insured proper mixing of the latter. The hydrogen used was freed of oxygen by means of a Deoxo purifier and dried by Drierite; the hydrogen sulfide was dried with Drierite and used as such.

**Conductivity Measurements**—The apparatus and experimental method were the same as those described in detail in connection with the study of electrical conduction in molten copper-iron sulfide mattes.[1] A four-terminal conductivity cell and an ac potentiometer circuit were used to measure specific conductance. The tubes of the cell were of silica and spectrographic graphite rods served as electrodes. The electrodes were fixed, by means of a rubber stopper, to a steel tube 4 in. long and 1 in. in diam. This tube was fitted in a 1 in. hole in the cooling head; this arrangement permitted removing or inserting the electrodes in the melt at will without opening the furnace.

**Materials**—The copper sulfide was made from copper turnings and pure sulfur. The two were reacted in a partially covered porcelain casserole over a Bunsen burner. The product so obtained consists of a mixture of black copper(I) sulfide and bluish copper(II) sulfide. This mixture was subsequently melted in an induction furnace, using a graphite crucible, under an argon atmosphere. The copious evolution of sulfur during this operation is due to the decomposition of copper(II) sulfide into copper(I) sulfide and the heating was stopped as soon as the sulfur evolution subsided. The melt was then cooled under argon. The resultant compound was steel gray in appearance and gave the following results on analysis—first batch: 79.65 pct Cu, 20.28 pct S (theoretical analysis, 20.14 pct S); and second batch: 79.35 pct Cu, 20.61 pct S.

**Analysis**—The copper sulfide analyses were made by precipitating the sulfur as barium sulfate and weighing. The copper was determined electrolytically. Some effort was spent to get reproducible results in the sulfur analysis; duplicates were made in all cases and the results agreed generally to within 0.1 pct. In some cases the error was higher than this, of the order of 0.5 pct. The average error may be considered to be of the order of 0.25 pct, which corresponds to approximately five units in the second decimal place of the stated sulfur figures. The failure to reach 100 pct in the overall analyses of some of the samples comes from the contamination of the melt by the silica of the electrodes. In a few cases difficulty was encountered in getting reproducible results in the copper determinations, which explains the high overall figures (samples 28, 29, 34).

**Procedure**—The crucible was charged with approximately 250 g copper sulfide and set in place in the furnace. The radiation shields and cooling head were installed and the furnace checked for leaks. At this point, the argon was turned on and the furnace flushed for approximately 30 min prior to heating. The temperature was increased at the rate of 2°C per min until the working temperature was reached. At this point, the gas inlet tube was lowered into the melt and the $H_2$-$H_2S$ mixture allowed to bubble into the latter at the rate of approximately 150 ml per min. The outgoing gas escaped through an oil trap into the fume hood. The conductivity of the melt was measured at periodic intervals. Between the measurements, the electrodes were left out of the melt so that a representative sample would be in contact with the graphite probes during the actual measurement. When the conductivity remained constant for at least 4 hr, an equilibrium state was presumed to be obtained and, at this point, the final value of the conductivity was noted, a final temperature reading was taken, the melt sampled by suction through a 4 mm quartz tube which dipped into the melt, and the ingoing gas analyzed if necessary.

## Results and Discussion

The experimental results are shown in Table I and Fig. 1, where the conductivity is plotted as a function of the mole fraction of sulfur in the melt at three temperatures: 1170°, curve 1; 1250°, curve 2; and 1300°C, curve 3. Curves 1 and 2 were determined under equilibrium conditions, i.e., by keeping an $H_2$-$H_2S$ atmosphere continuously over the melt during measurements. Curve 3 was determined under different conditions. The melt was kept saturated with pure hydrogen sulfide for 22 hr, at the end of which period the conductivity of the melt was measured and the melt sampled. Subsequently, the hydrogen sulfide atmosphere was replaced with a pure argon atmosphere and the melt thus allowed to desulfurize with proper mixing. The conductivity was determined periodically during desulfurization, and the melt sampled at each conductivity determination. As may be seen from the results, this

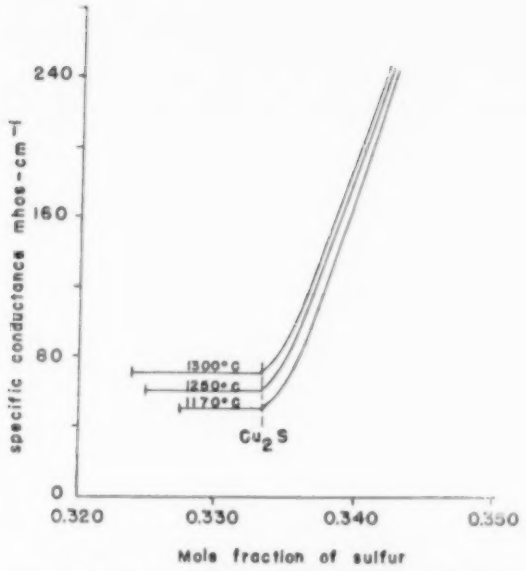


Fig. 3—Idealized plots of the specific conductance of liquid copper sulfide as a function of the mole fraction of sulfur.

curve does not differ greatly from the true equilibrium curves and it may be assumed that desulfurization of the melt was somewhat slow. As a general rule, $H_2$-$H_2S$ atmospheres were used to study sulfur-rich melts only. Copper sulfide melts having a sulfur content below that of stoichiometric value have low enough sulfur pressures to permit measurements of the conductivity without change in the sulfur content occurring during the measurement. The sulfur content of the low sulfur melts was varied by adding pure copper until saturation occurred.

Analysis of the ingoing gas showed that the experimental procedure was satisfactory. The results checked with those of Schuhmann and Moles in that the same composition of the melt corresponded to the same gas composition, within experimental errors. Consequently, after a few experiments, gas analyses were discontinued and the melt composition was used to determine the sulfur pressure in the furnace by referring to the results of the above authors.* The only case in which results differed considerably from those of Schuhmann and Moles was the one in which a pure $H_2S$ atmosphere was sent into the furnace to obtain a very high sulfur melt. The highest sulfur contents obtained in this work, with an atmosphere of pure hydrogen sulfide, were 20.75 pct at 1170°, 20.66 pct at 1250°, and 20.73 pct at 1300°C. Schuhmann and Moles had the following results: 21.43 pct at 1150°, 21.54 pct at 1250°, and 21.39 pct at 1350°C.

The distinctive feature of the graphs shown in Fig. I is that, for melts below stoichiometric $Cu_2S$ in sulfur content, the conductivity remains constant, and for those above the stoichiometric value, the conductivity increases sharply as a function of sulfur content. This behavior is very similar to that encountered in solid copper(I) sulfide. Kushida[9] found that, at low sulfur pressures, the conductivity of solid copper(I) sulfide ($\beta$ form) increased

* It should be mentioned that the ingoing gas composition was known approximately by reading the flowmeters. The purpose of the gas analyses was to determine the composition of the gas more precisely.

Table I. Composition-Conductivity Relations for Molten Copper Sulfide

| Sample | Cu, Pct | S, Pct | S, Pct, Corrected* | $N_S$ | Specific Conductivity | Temperature, °C |
|---|---|---|---|---|---|---|
| | | | | 0.3275† | 50 | 1170 |
| 9 | 80.15 | 19.77 | 19.79 | 0.3288 | 52 | 1174 |
| 10 | 79.55 | 19.92 | 20.03 | 0.3318 | 52 | 1170 |
| 7 | 79.18 | 20.36 | 20.45 | 0.3376 | 116 | 1166 |
| 12 | 79.00 | 20.69 | 20.75 | 0.3417 | 319 | 1176 |
| | | | | 0.3250† | 60 | 1250 |
| 18 | 79.97 | 19.58 | 19.67 | 0.3267 | 60 | 1246 |
| 17 | 79.85 | 19.78 | 19.85 | 0.3282 | 60 | 1240 |
| 16 | 79.80 | 19.85 | 19.92 | 0.3302 | 61 | 1243 |
| 15 | 79.70 | 19.87 | 19.99 | 0.3307 | 61 | 1243 |
| 14 | 79.60 | 20.11 | 20.17 | 0.3338 | 67 | 1244 |
| 13 | 79.35 | 20.15 | 20.25 | 0.3347 | 71 | 1246 |
| 24 | 79.60 | 20.19 | 20.23 | 0.3345 | 131 | 1244 |
| 23 | 79.35 | 20.55 | 20.57 | 0.3391 | 168 | 1244 |
| 22 | 79.17 | 20.62 | 20.66 | 0.3404 | 240 | 1252 |
| 33 | 80.00 | 19.90 | 19.92 | 0.3303 | 70 | 1305 |
| 34 | 80.25 | 20.02 | 19.97 | 0.3310 | 70 | 1300 |
| 32 | 79.80 | 19.99 | 20.03 | 0.3318 | 71 | 1300 |
| 31 | 79.90 | 20.18 | 20.16 | 0.3336 | 73 | 1293 |
| 29 | 80.10 | 20.27 | 20.20 | 0.3342 | 83 | 1303 |
| 30 | 79.45 | 20.12 | 20.21 | 0.3343 | 80 | 1295 |
| 26 | 79.30 | 20.40 | 20.46 | 0.3377 | 170 | 1292 |
| 28 | 79.60 | 20.73 | 20.66 | 0.3405 | 185 | 1290 |
| 25 | 79.20 | 20.71 | 20.73 | 0.3415 | 195 | 1293 |

* % S (corrected) $= \frac{\%\ S}{\%\ S + \%\ Cu} \times 100$.

† Value taken from the paper of Schuhmann and Moles.[11]

slightly with increasing sulfur pressures according to the relation

$$\log \sigma = \text{constant} + 3/2 \log p_{S_2}.$$

An abrupt increase in $\sigma$ was noted at sulfur pressures of 0.22 mm. Kushida correlated this increase with the transition of $Cu_2S$ to $Cu_{1.8}S$.

The behavior of liquid copper sulfide is somewhat similar, also, to that found in solid $Cu_2O$. Duenwald and Wagner[12,13] found that the conductivity of this compound increases with the oxygen pressure according to the law

$$\sigma \sim p^{1/5}_{O_2}$$

They interpret these results by introducing the following equilibrium

$$O_2\,(g) + 4\,e^- + 4Cu^{\cdot} \rightleftarrows 2Cu_2O + 4\,p^{\cdot} + 4Cu'_{\square}$$

where $p^{\cdot}$ indicates a newly created positive hole in the crystal lattice, and $Cu'_{\square}$ indicates a vacancy in the lattice of $Cu^{\cdot}$ ions. From this equilibrium equation, they deduce the relation

$$p^{\cdot} \sim p^{1/5}_{O_2}$$

i.e., the creation of new holes in the lattice is a function of the oxygen pressure to the 1/5 power. Thus, these new holes are responsible for the conduction in the crystal ($p$-type semiconduction) and the theoretical equation agrees approximately with the experimental equation. However, Böttger[14,15] has shown that the $p^{1/5}$ law is true for oxygen pressures greater than $10^{-7}$ atm. At lower pressures, he supposes that $Cu_2O$ behaves as an intrinsic semiconductor. Juse and Krutschatow[16] have shown that the activation energy for intrinsic semiconduction in solid copper oxide is 0.7 ev.

The experimental results for solid $Cu_2S$ and solid $Cu_2O$ may well be interpreted by the band theory. Both these compounds show p-type semiconduction when the pressure of the electronegative constituent is increased. Positive holes, created by the transfer of electrons from the valency band into the impurity levels, are responsible for conduction. On the copper-rich side, however, these compounds behave

as intrinsic semiconductors and conduction is due to the transfer of electrons from the valence band into the conduction band.

Derge, Pound, and Yang[7] have applied the band theory to liquids, in order to explain the experimental results obtained while investigating the conductivity and the current efficiency of the $Cu_2S$-CuCl system. They assume stoichiometric $Cu_2S$ to be an intrinsic semiconductor, and sulfur-rich $Cu_2S$ to be a *p*-type semiconductor by analogy to the situation in solid $Cu_2S$. The present work bears out this hypothesis. The constancy of the conductivity on the copper-rich side of $Cu_2S$ would indicate that in this region this compound behaves as an intrinsic semiconductor. Measurements of the conductivity of copper-saturated melts as a function of the temperature have been made and the results are shown in Fig. 2, where log of the conductivity is plotted as a function of 1/*T*. The conductivity thus follows the law

$$\sigma = Ae^{-\Delta E/RT}$$

and the slope of the straight line permits the energy of activation for conduction to be calculated, i.e., the width of the energy gap between the valence band and the conduction band. This value has been calculated to be 0.7 ev and is low enough to permit transfer of electrons from the valence band to the conduction band under thermal excitation.

The rapid increase of the conductivity as a function of the sulfur pressure on the sulfur-rich side of liquid copper sulfide indicates that sulfur-rich copper sulfide is a *p*-type semiconductor. Increasing the sulfur content of the melt has the effect of introducing impurity levels into the energy gap, with the result that electrons are transferred from the valence band into the impurity levels, thus creating additional holes which can transport current. It would be interesting to calculate the activation energy for conduction of sulfur-rich copper sulfides and obtain the width of the energy gap between the valence band and the impurity levels. However, because of the rapid increase of conductivity as a function of sulfur content and the uncertainties of the experimental measurements in this region, the present data do not justify this evaluation. The graphs shown in Fig. 1 have been redrawn and idealized in Fig. 3 to fit the picture presented here. In drawing these curves, the following facts have been kept in mind:

a) The lines on the copper-rich side have been extended to the solubility limit of copper as determined by previous workers.[11]

b) The curves of the sulfur-rich side have been drawn closer to one another to illustrate the fact that the energy gap between the valence band and the impurity levels is certainly smaller than the one between the valence band and the conduction band. This leads, therefore, to a smaller activation energy for conduction, with the result that variation of conductivity with temperature, at constant sulfur activity, should be smaller on the sulfur-rich side than on the copper-rich side.

Knowledge of the dependence of the conductivity on the sulfur pressure of liquid copper sulfide would permit theorizing on the mechanism of sulfur absorption. However, the discrepancy which exists between the results obtained in this work and those of Schuhmann and Moles[11] for pure $H_2S$ atmospheres introduces doubt as to the exact dependence of the conductivity on the sulfur pressure. More work will have to be done to check these data.

## Acknowledgments

The authors are indebted to Mrs. Mary Lou Uhl and Jack Shegog for experimental assistance, and to Mrs. Virginia F. Johnston and her assistants for chemical analyses. The research described in this paper was sponsored by the U. S. Atomic Energy Commission under Contract No. AT(30-1)-1024.

## References

[1] G. Derge, G. M. Pound, and G. Osuch: *AIME Trans.*, 1955, vol. 203, p. 481; JOURNAL OF METALS, March 1955.
[2] G. Derge, G. M. Pound, and L. Yang: *AIME Trans.*, 1956, vol. 206, p. 783; JOURNAL OF METALS, June 1956.
[3] H. Inouye, J. W. Tomlinson, and J. Chipman: *Trans. Faraday Soc.*, 1953, vol. 49, p. 796.
[4] H. W. Henkels: *Journal of Applied Physics*, 1950, vol. 21, p. 725.
[5] V. A. Johnson: *Physical Review*, 1955, vol. 98, p. 1567.
[6] A. Epstein and H. Fritzsche: *Physical Review*, 1954, vol. 93, p. 922.
[7] A. Epstein and H. Fritzsche: *Physical Review*, 1954, vol. 94, p. 1426.
[8] E. Hirahara: *Journal* Physical Soc., Japan, 1951, vol. 6, pp. 428-437.
[9] T. Kushida: *Journal of Science* Hiroshima University, 1952, vol. 16, series A, pp. 75-80; *Chemical Abstracts*, 1953, vol. 47, p. 7864.
[10] I. Yokota: *Journal* Physical Soc., Japan, 1953, vol. 8, pp. 595-602; *Chemical Abstracts*, 1954, vol. 48, p. 4902.
[11] R. S. Schuhmann and O. W. Moles: *AIME Trans.*, 1951, vol. 191, p. 235; JOURNAL OF METALS, March 1951.
[12] H. Duenwald and C. Wagner: *Ztsch. für physikalische Chemie*, 1933, vol. B22, p. 212.
[13] O. Böttger: *Annalen der Physik*, 1952, vol. 10, p. 232.
[14] W. Jost: *Diffusion in Solids, Liquids and Gases*, p. 390. Academic Press, New York, 1952.
[15] B. Claudel: *Bulletin* societe chimique de France, 1956, p. 708.

**Discussion** of this paper sent (2 copies) to AIME by Jan. 1, 1958 will appear in AIME *Transactions* Vol. 212, 1958, and in JOURNAL OF METALS, October 1958.

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## Corrections

"Effect of Oxygen Input Rates In the Decarburization of Chromium Steel," by G. W. Healy and D. C. Hilty, *AIME Trans.*, 1957, vol. 209, p. 695; JOURNAL OF METALS, May 1957.

The graphs presented in Figs. 6 and 10 were transposed.

"Equilibria in Reactions of Hydrogen, and Carbon Monoxide With Dissolved Oxygen in Liquid Iron; Equilibrium in Reduction of Ferrous Oxide With Hydrogen, and Solubility of Oxygen in Liquid Iron," by Nev A. Gokcen, *AIME Trans.*, 1956, vol. 206, p. 1558; JOURNAL OF METALS, November 1956.

Page 1561, 6th line from the bottom, column 2, "apparatus" should have been "apparatuses". Eq. 7 on page 1563, *F* should have been $\Delta F^\circ$. Page 1565, first line above Eq. 21, "Eq. 18" should be "Eq. 16". Page 1565, in Eq. 26, first term after = sign should be minus (−).

by V. F. Leferrer

# Vacuum Dezincing of Parkes' Process Zinc Crusts

*A new process for the treatment of silver crusts from desilverization of lead has been developed by Société de Penarroya. The zinc contained in the crusts is recuperated by vacuum distillation at low temperature. The use of special retort crucibles is avoided.*

AT Noyelles-Godault the Parkes process (zinc addition to a silver-bearing lead melt) is used to desilverize lead bullion from the blast furnace.

The crust which rises to the surface of the bath is removed and pressed by a well-known process in a press of the Howard type. The pressed crust, called zinc crust or silver crust, contains 10 pct Ag, 30 pct Zn, and 60 pct Pb. It is melted under a salt bed in a small, narrow, and deep kettle heated only in its upper part. A liquid concentrated alloy is obtained which is called T.A.C. in France (triple alliage concentré) analyzing approximately 25 pct Ag, 65 pct Zn, 8 to 10 pct Pb, and 1 to 1.5 pct Cu. This T.A.C. is a real metallic alloy, completely deoxidized, and can be stored indefinitely.

The process used at Noyelles-Godault consists in distilling this alloy in a tight furnace, under low vacuum and at low temperature, so that only the zinc distills and is condensed into liquid form. The residual silver-bearing lead is almost entirely free from zinc and oxidized dross.

The vacuum dezincing equipment, see Figs. 1 and 2, consists of:

1) A furnace, constituted of a casing of steel plate lined with refractory bricks, heated internally by means of graphite resistors. The temperature of the furnace is measured by a thermocouple device and controlled by an automatic temperature regulator which acts upon the flow of the current passing through the resistors. Two doors, numbered 1 and 2 in Fig. 2, are provided for, one for charging the T.A.C., the other for tapping the high silver-bearing lead.

2) A condenser, and an ordinary room lined with good heat conductor refractory material. This condenser is provided with a graphite resistor which serves to bring to temperature when starting the furnace. A thermocouple records the temperature of the zinc melt and controls the temperature in the furnace, that is, the flow of current through the resistors, by means of the above mentioned regulator, so that the distillation rate in the furnace does not exceed that of the condensation. The condenser is connected to the vacuum pump by a filter. The whole equipment should, of course, be fluid-tight. The operation is carried out under a vacuum of about 10 mm Hg.

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TP 4496D. Manuscript, Feb. 3, 1956. New York Meeting, February 1956.

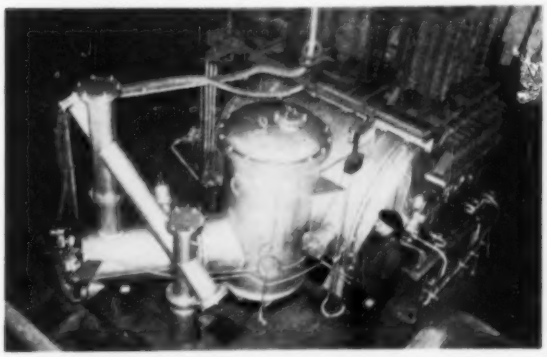

Fig. 1—Photograph of vacuum dezincing furnace.

Table I. Commercial Results of a Year's Operation

| Products | Kg | Pct Pb | Pct Ag | Pct Zn |
|---|---|---|---|---|
| **Charged** | | | | |
| T.A.C. | 1000 | 8 | 25 | 65 |
| Lead | 300 | | | |
| **Obtained** | | | | |
| High silver-bearing lead | 650 | 37 | 38 | 1.75 |
| Zinc | 630 | 1.8 | 0.15 | 98 |
| Blue powder | 20 | | | |
| Dross | | 3 | 0.15 | 94 |

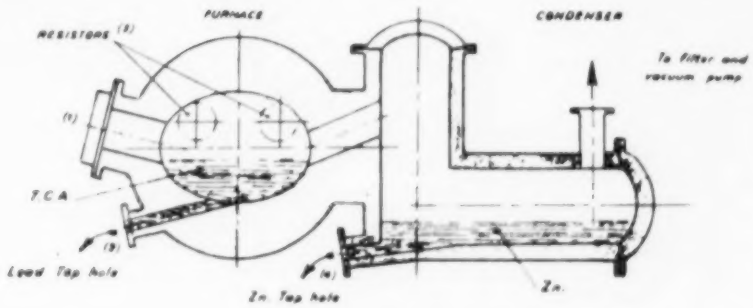


Fig. 2—Diagramof vacuum dezincing furnace.

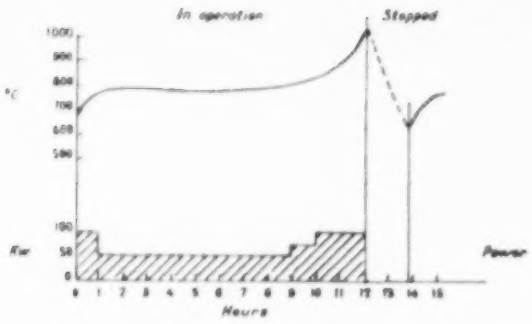


Fig. 3.—Graph of furnace temperature under vacuum.

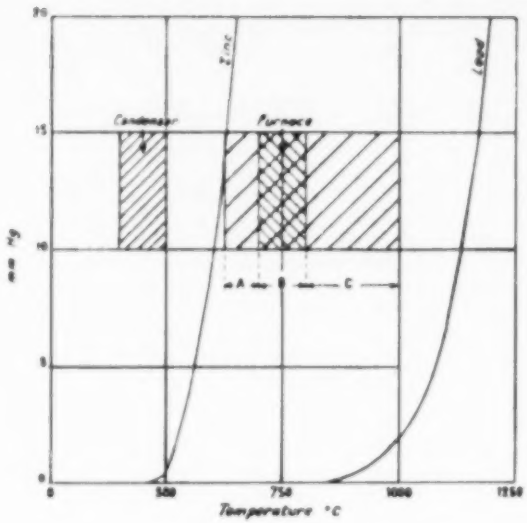


Fig. 4—Graph of zinc and lead vapor pressure curve dependent on temperature.

## Operating Conditions

The process is discontinuous. For the furnace in operation at Noyelles-Godault, the charge per batch is of 1000 kg of T.A.C., to which 300 kg Pb drawn from the liquation kettle is generally added. At Noyelles-Godault, the concentration is very high so as to obtain a perfectly homogeneous liquid alloy that can be stored without undergoing any alteration through oxidation; this is one of the reasons why lead which only corresponds to a small part of the lead drawn off previously is added at the distillation. This lead addition also serves to lower the melting point of the T.A.C., obtaining a better zinc distillation at lower temperature and saving power. In works where the concentration is not so thorough, this addition of lead would not be necessary.

The temperature of the condenser is maintained at 450°C; that of the furnace is shown in Fig. 3. Except for charging the furnace (beginning of the operation) and tapping the metals (zinc and silver-bearing lead), the operation is entirely automatic.

The temperature in the furnace varies between 750° and 800°C during the operation. It rises at the end since the flow of zinc vapors stops, and, therefore, the temperature in the condenser lowering continually, the temperature-regulators maintain the resistors of the furnace under voltage. The operation is then stopped, the vacuum is broken, and the molten metals are tapped. The furnace is charged anew and shut; another operation starts. In short, it is the condenser temperature which controls the distillation rate.

Fig. 4 shows the vapor pressure curve of lead and zinc dependent on temperature, and the temperature and depression conditions of both furnace and condenser. It can be observed that the conditions maintained in the furnace are far enough from the lead volatilization curve and those in the condenser at quite a distance from the zinc volatilization curve.

The commercial results on an average of a whole year's operation, brought down to a 1000 kg T.A.C., are shown in Table I.

Zinc recovery is better than 95 pct, and 99 pct of the silver from the T.A.C. is immediately recovered in the high silver-bearing lead to be cupelled.

The total power consumption is from 800 to 850 kw-hr per metric ton of T.A.C.

The furnace operating at Noyelles-Godault has a capacity of about 2000 kg of T.A.C. per day, corresponding to 500 kg Ag. At Oued-el-Heimer, the furnace will have a capacity of about 850 kg of T.A.C. per day, corresponding to about 200 kg Ag.

## Process Advantages

The old distillation process, using graphite retorts, presents the following disadvantages:

1) All the zinc contained in the zinc crust is not recovered in distilled zinc form. Consequently, there remains fairly large amounts of zinc in the lead to be cupelled, making cupellation more difficult.

2) The graphite crucibles are expensive and have a short working life. Their capacity is rather small and a great number of retort furnaces are therefore necessary to treat the zinc crust in one plant.

3) Mixed lead and zinc oxides of high silver content form in the crucible and have to be reduced to obtain another silver-bearing lead for cupellation, mainly when zinc crust has not been concentrated.

Vacuum dezincing has the following advantages:

1) Distillation is at low temperature, which means low power consumption, low maintenance cost of the furnace, and good zinc recovery.

2) No more graphite crucibles are necessary.

3) There is neat separation of the elements: lead and silver are on one side, zinc is on the other.

4) The furnace is operated automatically. Manual labor is only necessary for charging the furnace and tapping the metals.

5) There are no more mixed Pb-Zn oxides to be retreated. Therefore, there is good silver recovery, and cupellation and reduction costs are considerably reduced.

6) It is possible to build furnaces of large capacity, and have only one distillation furnace per plant.

## References

[1] A. W. Schlechten and C. H. Shih: A Better Way to Treat Parkes' Crusts. *Engineering and Mining Journal*, 1949, vol. 150, No. 12, pp. 80-81.

[2] A. W. Schlechten and R. F. Doelling: Vacuum Treatment of Parkes' Process Crusts on a Pilot Plant Scale. *AIME Trans.*, 1951, vol. 191, pp. 327-330; JOURNAL OF METALS, April 1951.

[3] T. D. Souza Santos: *Boletim da Associação Brasileira de Metais*, 1952, vol. 8, No. 28, pp. 312-337.

**Discussion** of this paper sent (2 copies) to AIME by Oct. 1, 1957 will appear in AIME *Transactions* Vol. 212, 1958, and in JOURNAL OF METALS, October 1958.

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# AIME NEWS

## Powder Metallurgy Symposium in Chicago

As part of the World Metallurgical Congress, November 4 to 8 in Chicago, there will be a Powder Metallurgy Symposium co-sponsored by the Metal Powder Association and the American Society for Metals. The Symposium is scheduled for the afternoon of Thursday, November 7, at the Palmer House.

Among the topics to be discussed are: Current Advances in the Science of Powder Metallurgy, by J. E. Burke and H. H. Hirsch, General Electric Co.; Development of Iron Powder for Powder Metallurgy by the H-Iron Process, by J. F. Kuzmick, Consultant for Alan Wood Steel Co.; and Metal Powders to Solid Strip—The Present Status of Commercial Production, by W. N. Hayden, Hayden Metals Inc., and J. D. Shaw and W. V. Knopp, S-K-C Research Associates.

The Symposium will be under the co-chairmanship of George A. Roberts, President, and Kempton H. Roll, Executive Secretary, Metal Powder Association.

During this same week, the ASTM Committee B-9 and the Sub-Committees I, II-A, and III-A, B, C, D, and E are scheduled to meet at the Drake Hotel. These Meetings will take place on Tuesday and Wednesday, November 5 and 6.

## Titanium Symposium Planned by IMD Group

At the IMD Fall Meeting to be held in Chicago, the IMD Titanium Committee is sponsoring their Annual Titanium Symposium, to be held on Thursday, Nov. 5, 1957. The Symposium will be an all-day session under the direction of Lee S. Busch, director of engineering, Mallory-Sharon Titanium Corp. Mr. Busch, who will open the Symposium, will introduce the keynote speaker, John H. Garrett, executive secretary, Coordinating Committee on Materials, Office of the Assistant Secretary of Defense.

The morning session will be devoted to Titanium's Progress, at Home and Abroad. Lead-off speaker will be W. J. Harris, Jr., Advisory Panel on DOD Sheet Rolling Program, who will discuss U. S. Progress in Titanium, 1956-1957. Second speaker on the session will be Eric Swainson, ICI Metals Division, Birmingham, England, who will discuss European Progress in Titanium. There will be ample time during the session for questions from the audience.

The afternoon session will be devoted to a panel discussion of Opinions and Ideas on the Manufacture and Use of Titanium. Introductory remarks will be delivered by Lee S. Busch and the panel and discussion moderator will be N. E. Promisel, Airframe Materials Branch, Bureau of Aeronautics, Navy Dept. Members of the panel include: R. S. Reinhold, Boeing Airplane Co.; A. Hurlich, Convair; W. Sharp, Pratt & Whitney Aircraft Corp.; W. J. Wile, General Electric Co.; C. B. Voldrich, Battelle Memorial Institute; Col. J. N. Dick, U. S. Air Force; N. L. Reed, U. S. Army; W. E. Lusby, DuPont Co.; W. W. Minkler, Titanium Metals Corp. of America; L. S. Busch, Mallory-Sharon Titanium Corp.; T. E. Perry, Republic Steel Corp.; and W. L. Finlay, Rem-Cru Titanium Inc. As in the past, there will be ample time for questions from the audience.

## Electric Furnace Men Will Congregate In December at Pittsburgh

Final plans are being made for the Fifteenth Annual Electric Furnace Steel Conference to be held at the Penn-Sheraton Hotel, Pittsburgh, December 4, 5, and 6. The text of the preliminary program is given on page 1462.

The Plant Trip has been scheduled for the first day of the Meeting, Wednesday, December 4, preceding the technical sessions. Both the Plant Trip and technical sessions will draw operating men, repair and maintenance men, metallurgists, ceramic and refractory engineers, observers, and others interested in the production of more, better, and cheaper steel.

The complete and final program for the meeting will be published in the December issue of JOURNAL OF METALS. Hotel reservations can now be made directly with the Penn-Sheraton Hotel or others in Pittsburgh. The Electric Furnace Steel Committee is now accepting advance registrations at AIME headquarters in New York.

The $7.00 registration fee also includes a copy of the bound Proceedings when published. There is a $2.00 reduction in the registration fee for AIME members.

Available at this time are copies of the 1956 Proceedings for those who did not attend the 1956 Conference. These are available through mail orders at $10.00 to nonmembers and at rates of 30 pct less to AIME members and past conference registrants. For foreign orders, add $.50 for postage.

## World Metallurgical Congress in Chicago

The World Metallurgical Congress will be held in Chicago the week of November 2, 1957. During that same week, the Metallurgical Society of AIME will hold its IMD Fall Meeting and there will be a special one day technical session arranged by the Iron & Steel Div. At the same time, ASM will hold its annual Exhibition and Meeting.

As part of the Congress, several technical sessions will be held on Wednesday, Thursday, and Friday, November 6, 7, and 8. The session to be held on Wednesday morning will cover progress in nonferrous metallurgy. Among the subjects to be discussed are recent developments in nonferrous metallurgy, the report and document library at Armour Research Foundation, and design of a punch-card system as an example of literature research at Armour Research Foundation.

*(Continued on page 1462)*

## Metal Congress

*(Continued from page 1461)*

Among the speakers will be O. T. Barnett, D. W. Levinson, Mary Murray and Ann Wennerberg, all associated with Armour Reseach Foundation.

The Thursday morning session on Progress in Ferrous Metallurgy will be held at the International Harvester Co. Central School in Chicago. R. H. Aborn, Director of the Edgar C. Bain Laboratory for Fundamental Research, U. S. Steel Corp., will discuss recent advances in ferrous research. Metallurgy and Physics will be covered by D. S. Lieberman, University of Illinois. M. C. Metzger, Universal Cyclops Steel Corp., will cover Developments in High Temperature Alloys.

The international aspects of literature research will be covered at a session on Friday morning at the International Harvester Co., Central School. Some of the topics to be covered at this session include: The Technical Library and Information Services for the British Metallurgical Industries, Activities and Functions of the Centre de Documentation Siderurique, Bibliographic Services within Aluminium-Industrie, and Importance of Documentation. Some of the speakers will be Anthony Post, the Iron and Steel Institute, London; Marc Allard, Centre de Documentation, Siderurique, St. Germain-en-Laye, France; Ernst A. Bloch, Aluminium-Industrie, Switzerland; and Frank T. Sisco, Engineering Foundation, New York.

Also scheduled as part of the Congress proceedings is a talk by H. Luling, chief metallurgist, Georg Fischer Aktiengesellschaft, Switzerland, who will describe the scope and function of the new library recently established by this European iron foundry. The exact time for his talk has not yet been set.

## Building Coordinator Named for New Center

Col. Clarence E. Davies, Secretary of ASME, has been named as Building Coordinator of the new United Engineering Center to be erected on United Nations Plaza between 47th and 48th Streets. His appointment was announced by Walter J. Barrett, president of United Engineering Trustees, Inc.

Col. Davies sailed for Europe in August to extend an invitation to representatives of thirteen European engineering societies to share in the facilities in the new Center. He was accompanied by O. B. Schier who will become Secretary of ASME later this year, when Col. Davies retires. Col. Davies will devote his time for the next few years to plans for the new Engineering Center.

The Conference of Representatives of the European Engineering Societies and Representatives from American Societies will be held in New York during the week of April 28, 1958. At that time, formal action is expected to be taken on the invitation to the European groups to join in the new Center.

## Volume IV Nuclear Metallurgy Published

The Metallurgical Society of AIME announces that the Volume IV on Nuclear Metallurgy has been published. Contained in this volume are sixteen papers on uranium and uranium dioxide, presented at the IMD Fall Meeting on November 6th in Chicago. This Volume IV costs $7.00 for nonmembers and $5.00 for members. AIME members may be billed. For nonmember foreign orders, add $.50 for mailing. Mail orders will be filled after November 7th.

Volumes I, II, and III of Nuclear Metallurgy series can also be ordered by mail. These each cost $3.75 for nonmembers and $2.50 for members.

# 1957 Electric Furnace Conference

## Preliminary Program

### WEDNESDAY, DECEMBER 4

**9:00 am to 9:00 pm Registration**

**10:00 am Plant Trip to Babcock and Wilcox Co., Beaver Falls, Pa.**

Chartered buses will leave from the Grant Street entrance of the Penn-Sheraton Hotel at 10 am. Lunch will be provided by the host company. Buses will return to the Penn-Sheraton Hotel by 5 pm.

### THURSDAY, DECEMBER 5

**8:30 am Registration**

**9:30 am Opening Session**

Welcoming remarks; announcements; reports.

**9:45 am Joint General Session on Nitrogen in Electric Furnace Steel**

Application of nitrogen solubility data to alloy steelmaking; nitrogen-porosity relations in chromium-nickel-manganese steels; sampling and analysis of nitrogen in electric furnace steels—review and evaluation of modern methods.

**2:00 pm Joint session on Refractories**

Cast and rammed sections in arc furnace roofs; Canadian basic refractory practice in electric furnaces; tar-bonded basic refractories; furnace bottoms—installation of thermocouples in electric furnace hearths; ladle refractories.

**6:30 pm Reception and Cocktail Party**

**7:00 pm Annual Fellowship Dinner**

Speaker: Edward A. Livingstone, vice president, The Babcock and Wilcox Co., Head of the Tubular Products Div., Beaver Falls, Pa.

Toastmaster: Stanley M. Norwood, Assistant to President, and vice president, Electro Metallurgical Co., Div. of Union Carbide Corp., New York, N. Y.

### FRIDAY, DECEMBER 6

**8:30 am Registration**

**9:30 am Ingot Session on Vacuum Melting: Electric Arc Furnace Practice Variables on Quality**

Overall summary of vacuum melting; consumable electrode vacuum melting; induction vacuum melting; furnace practice variables and their effect on quality of aircraft and bearing steels—panel discussion.

**9:30 am Castings Session on Foundry Practices**

Oxygen as an aid in electric furnace melting; some aspects of melting low-temperature, high-impact steels; spectrographic analysis in foundry.

**2:00 pm Joint Session on Economic Utilization of Power**

Power utilization and control in the electric furnace steel plant; an effective demand limiting system for the electric furnace melt shop; improvements in arc furnace power regulation and electrode hoisting systems; analysis and practical results obtained from a study of arc furnace controls.

## High-Strength Steel Conference in May

The Iron and Steel Division of The Metallurgical Society of AIME will sponsor a regional conference in Pittsburgh on May 5 and 6, 1958, on High-Strength Steel.

General conference theme is high-strength steels and their applications for special projects, such as aircraft. Among the subjects to be covered are the environment, uses and required properties; factors in structure and composition of steels leading to desired properties; air melting of super-duty steels; and special steel-making practices.

Some of the specific papers scheduled for the conference will cover aircraft engineering, aircraft and rocket stuctures, and atomic energy. The tensile properties, notch toughness, corrosion resistance and oxidation resistance, ductility and environmental resistance, and structural stability will also be covered.

Such specific topics as chemistry ranges, cleanliness requirements, control of segregation, and hot rolling processes will be discussed at the third session. The session on special steelmaking practices will cover consumable electrode melting, vacuum casting of air-melted steels, vacuum melting and casting techniques, and new practices for working steels.

## EJC Salary Survey

Engineers Joint Council conducted surveys in 1953 and 1956 to determine the salary structure of the engineering profession. The results were published separately as "Professional Income of Engineers" in 1954 and 1957. The survey is the most comprehensive and representative study generally available on the subject. The EJC staff responsible for the statistical compilation and analysis of the data of the surveys have completed a comparison of the two studies. The summary results of the comparison are presented herein.

The 1956 sample was greatly expanded over that for 1953 (107,832 vs. 69,061); however, the data of each survey are essentially comparable. The increase was due in part to a considerable expansion of engineering staffs of the participating organizations, and in part to new participants in the 1956 survey. A review of the returns of these new participants has been made by the EJC staff and it was found that there were no material deviations of their data from that of the overall salary structure. The conclusion of the staff is that the surveys are comparable.

There are some variations in trends when each of the various industrial classifications of the survey are compared, but it would be most productive and meaningful, at this time, to analyze the structure of the entire industrial sample for both surveys. This means we shall consider the salary structure of all engineers covered in the various industrial and private activities (excluding thus, governmental and educational engineers). For ready reference the data was presented in Table VI page 14 of the 1953 study and Table VI page 15 of the 1956 survey. The various line groupings in the salary structure—median, quartiles and deciles—follow, with minor variations the same general trends, and for the sake of simplicity the MEDIAN line will serve as a basis of comparison. The relative change in salary will be reviewed in terms of percentage increase above the 1953 levels.

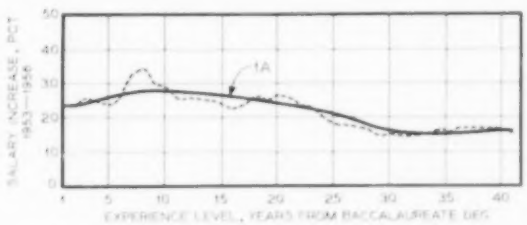
The first consideration will be the increment for each experience level or position—that is, the median salary for engineers with one year experience (referred to years from baccalaureate degree) in 1953 will be compared with the median salary for engineers with one year experience in 1956. This would mean comparing what the 1952 graduate was earning in 1953 with what the 1955 graduate was earning in 1956. The same basis is used all along the line for all experience levels. The increases (as percentage) have been computed and plotted in graph 1. It is shown that for engineers with up to 22 years of experience the salary rise was over 24%, reaching a maximum of 35% at 8 years experience; this trend tapers off from the 22 year level (22 YFD—year from degree, or experience) and levels out for the older engineers at about 17% rise.

It should be noted here that the engineering profession is composed, in the majority, of a youthful group. Therefore, the period covered between 0 and 22 YFD (where the largest increments occurred) contains probably 75% of the engineering population. The curve labelled 1A is an "average line" of increase which has been drawn to smooth out the fluctuations and indicate the overall trends.

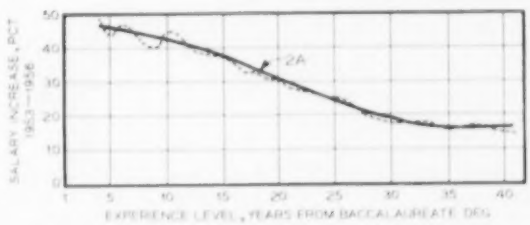
The next consideration is based on a comparison of the increments for each group of engineers to trace the career salary progression. In this case the engineers who graduated in 1952 and had one year experience in 1953 are the same represented as having four years experience in 1956 and their relative salary movements are studied. The computed salary increments are plotted in graph 2. It can be observed again that the larger increments occur in the areas of greatest population density, covering the same span as noted above. Up to 20 YFD the increment is above 30%, in fact well above 40% for those with up to 13 year experience. It does again taper off at about the same level as for the position comparison.

For the same period (1953-1956) U. S. Department of Commerce figures indicate that earnings of all full-time wage and salary employees rose 12%, and of full-time manufacturing wage earners rose 13%; Bureau of Labor Statistics figures indicate that, for the same period, the Gross National Product increased about 13%, the Wholesale Price Index 4% and Consumer Price Index 3%.

Conclusion: An impressive upward adjustment occurred in engineers salaries between 1953 and 1956. To the best knowledge of the staff of EJC responsible for these studies, this rise is unparalleled in the recorded history of the engineering profession.




Graph 1. Salary increases as percentages have been computed and plotted in relation to position or experience. The base year is 1953 and the increase curve is based on the year 1956.




Graph 2. Salary increase was plotted as it related to individuals. Again the base year was 1953 and the increase curve plotted was based on the year 1956.

## News of New Powder Metallurgy Group

A new association, the Powder Metallurgy Parts Manufacturers Assn., was organized a few months ago. Its membership comprises companies who make and sell structural and bearing parts formed of powder metal.

Among its goals are to promote wider use and to improve the quality of powder products, to promote standardization of powder-metallurgy products, including their composition, the physical properties of finished units, and pertinent testing methods.

The group plans to develop industry-wide standards and testing methods for raw materials used in the industry. This will be done in cooperation with producers of metal powders. The group anticipates the distribution of technical knowledge of powder metallurgy processes to colleges and universities, to other associations, and to those segments of the general public interested in the process.

One method of procedure will be to establish a clinical program in cooperation with various technical societies. As part of that program, top technicians will meet with personnel of technical societies to inform them of the latest development in the powder-metallurgy field and to relate the most efficient and economical use of powder-metallurgy parts. A technical committee plans the development of a "User's Handbook" on the purchase and use of powder-metallurgy parts.

At a recent meeting of the directors of this association, the term "powder-metallurgy parts was adopted to replace "sinterings" as the product designation for structural and bearing units produced by the members. This action was taken because sintering is only one process among many phases of production that are required. It is hoped that the new term will replace the term "sinterings" in all correspondence, literature, and technical papers issued by members of the association, except in reference to the heat treatment process which will still be indicated by the original term.

## Metallurgical Society Plans for February

Plans for The Metallurgical Society participation in the AIME Annual Meeting are progressing rapidly. The Meeting this year will be held in New York on February 16 to 20. Headquarters for The Metallurgical Society will be the Sheraton-McAlpin Hotel.

The opening session, held on Sunday afternoon at the Sheraton-McAlpin, will be an education session sponsored by The Metallurgical Society committee on education. This year, each of the societies will sponsor their own education session on Sunday afternoon. All three societies will meet at the Hotel Statler for dinner on Sunday evening. Dinner will be followed by a general session for all three groups, to be sponsored by the Council on Education of AIME.

Details of the technical sessions for The Metallurgical Society Meetings will be announced in JOURNAL OF METALS after they have been put into final form. As has been customary in past years, there will be a Dinner-Smoker held on Monday evening for all those attending the AIME Annual Meeting. The Metallurgical Society will hold a Banquet on Tuesday evening, after which there will be an informal dance.

On Tuesday afternoon, there will again be an all-Institute technical session as was scheduled for the New Orleans Meeting last year. This session will be followed by the AIME Annual Business Meeting.

All AIME members attending the Meeting will gather on Wednesday evening for the Annual AIME Banquet. On this occasion, the Incoming President of the Institute, Augustus B. Kinzel will be installed. Also part of the Banquet proceedings will be presentation of AIME Awards for the year, and announcement of the members of the Legion of Honor for 1958.

The meeting will wind up on Thursday, with the last technical sessions being held Thursday afternoon. For those who feel in the need of relaxation after the rigors of the Meeting, a post-convention trip has been planned to Bermuda and Nassau. For details about this trip, see the October issue of JOURNAL OF METALS.

## Clifford Furnas Receives Frank J. Tone Medal

The AIME Niagara Frontier Section has announced that Clifford C. Furnas, Chancellor of the University of Buffalo, has been awarded the Frank J. Tone Medal for 1957 for his achievements in science and research.

The medal was established by F. Jerome Tone, director of the Carborundum Co., and Franchot Tone, well known actor, to honor the memory of their father, Frank J. Tone, former president of the Carborundum Co. and an outstanding scientist and inventor.

The medal was awarded to Dr. Furnas not only for his contributions to metallurgical research but also for his continuing and unusually capable leadership in finding solutions to problems in the field of metallurgical research and education. Born on Oct. 24, 1900, at Sheridan, Indiana, Dr. Furnas is a graduate of Purdue University. He received a Doctor of Philosophy degree from the University of Michigan and an Honorary Doctor of Engineering degree from Purdue in 1946.

Until 1930, he was engaged in metallurgical research work for the U. S. Bureau of Mines, later joining Yale University as Associate Professor of Chemical Engineering. In 1943 he became Director of the Curtiss-Wright Research Laboratory in Buffalo. When the Laboratory was transferred to Cornell University, he became Director of the Cornell Aeronautical Laboratory in 1946.

In 1954, he became Chancellor of the University of Buffalo. Granted a leave of absence, he served as Assistant Secretary of Defense for research and development from 1955 to 1957.

## Mervin Kelly to Head Building Fund Drive

Mervin J. Kelly, President of Bell Telephone Laboratories, Inc., has been named general chairman of the business and industry campaign for the new $10 million United Engineering Center to be erected on United Nations Plaza. His appointment was announced by Walter J. Barrett, president of United Engineering Trustees Inc.

Dr. Kelly has had broad experience in directing research and development programs, not only for the Bell Telephone System but also on military projects undertaken by Bell Laboratories for the Armed Forces. He has held many public assignments in Washington, particularly with the Atomic Energy Commission, the Dept. of Commerce, and the Dept. of Defense. Among many honors awarded to him are the Air Force Exceptional Service Award and the 1953 Trophy of the Air Force Assn.

Dr. Kelly has announced that the campaign for funds for construction of the new Engineering Center will commence later this year. Initial efforts in this drive will be directed toward those businesses and industries which are most dependent upon the technologies represented by the engineering societies.

## 1958 Annual Reactive Metals Meeting to Be Held in Buffalo

The Third Annual Reactive Metals Conference is scheduled to be held at the Hotel Statler, Buffalo, on May 27, 28, and 29, 1958. The meeting will be under the sponsorship of the Niagara Frontier Section of AIME. The general subject of the conference is those metals which, by pres-

*(Continued on page 1465)*

## Reactive Metals

*(Continued from page 1464)*

ent standards are difficult to process by conventional means, due to their reactivity with the more common refractories—oxygen or nitrogen.

The production, properties, fabrication, and application of tantalum, columbium, titanium, zirconium, hafnium, vanadium, molybdenum, tungsten, thorium, uranium, and their alloys will be discussed during the various technical sessions.

General Chairman for the Meeting is S. F. Urban, Titanium Alloy Manufacturing Div., National Lead Co. The other members of the Conference committee are: Administration, C. D. Roach; Arrangements, E. L. Gielzen; Exhibits, R. K. Kulp; Finance, W. W. Stephens; Plant Visitations, C. Fogel; Program, W. Clough; Publicity, C. W. F. Jacobs; and Registration, C. H. Emery.

Technical Sessions will be held during the day and outstanding events are planned for the evening. One evening will be devoted to a panel discussion on the future of the reactive metals. Outstanding evening event of the Meeting will be a Fellowship Hour and Banquet, at which a speaker of national reputation will address the delegates.

An exhibition pertinent to the entire field of reactive metals will be on display at the Statler Hotel during the Conference.

## "EJC's Report on What's Happening in Engineering"

### Nuclear Congress 1958

March 17 to 21, International Amphitheater, Chicago—H. Q. Hotel, Palmer House. Comprises 4th Nuclear Engineering and Science Conference; 4th International Atomic Exposition; 6th Hot Laboratories and Equipment Conference; 6th Atomic Energy in Industry Conference. Sponsorship to date: 30 national groups; Overwhelming number of papers already submitted. Advance program to be published Nov. 15, 1957. For information address Congress Manager, AIChE, 25 West 45th St., New York City, or your own society secretary. EJC coordinates. Congress theme is "Industrializing the Atom" and newly declassified information will be made public for the first time.

### Water Policy Report

EJC 1957 Restatement of Principles of a Sound National Water Policy—updating 1951 report—on "Best seller list" with more than 5000 copies now distributed to industry, government and education. Still available from EJC, 29 W. 39th St., New York City at 25 cents a copy. Bulk discount available.

# AROUND THE SECTIONS

• The **Montana Section** held its meeting on September 21 jointly with the Anaconda Aluminum Co. and Technical Society in the new employes' club at Columbia Falls, Mont. Following a dinner and business meeting, Mr. Frank Armes, supt. of the aluminum rod and wire mill of the Anaconda Wire and Cable Co., was the featured speaker. He gave an informative talk on the new *Great Falls Aluminum Rod and Wire Mill.*

• The first meeting of the **New York Powder Metallurgy (Hob-Nob) Group** was held on October 17 at the Metropolitan Room of the Brass Rail Restaurant, New York. Jerome F. Kuzmick, consultant for Alan Wood Steel Co., spoke on *Development of Iron Powder by the H-Iron Process.*

• The **New York Physical Metallurgy Group** will hold a meeting on Jan. 15, 1958 at the Federal Telecommunication Laboratories of the International Telephone and Telegraph Corp., 500 Washington Ave., Nutley, N. J. The featured speaker will be Dr. Robert M. Fisher of the U. S. Steel Corp. research center who will discuss *Applications of Electron Optics in Metallurgical Research.* The Group has another meeting scheduled on Mar. 24, at the American Brake Shoe Co. research center in Mahwah, N. J. A talk by Dr. Arthur S. Nowick, of the IBM Watson Laboratory will be on the agenda.

*Motion Pictures,* **a new film catalog distributed by United States Steel, lists 17 films of general interest, documentary and educational value which are available free except for shipping charges. The pictures offered are 16-mm sound and silent prints, some available in 35-mm. Many of the films presented are in full color. Included in the booklet, is useful information for prospective exhibitors.**

*Westinghouse Sound Films,* **a catalog of 16-mm sound films available free except for shipping charges, lists some 47 product information, general interest, and training motion pictures. Copies of the catalog, booklet B-7077, are available from Westinghouse Electric Corp., P. O. Box 2099, Pittsburgh 30, Pa.**

*The Man in the Doorway* **is a new 16-mm sound and color film produced by the American Cyanamid Co. as a tribute to the chemical industry as part of their 50th anniversary program. Prints of the picture, whose theme is conservation, may be obtained from Miss Norma Anderson, 30 Rockefeller Plaza, New York 20, N. Y.**

*The United States Steel Film Distribution Centers* **have released a new series of films which are available free except for shipping charges. The film distribution centers are located as follows:** *Birmingham Film Distribution Center,* **Tennessee Coal and Iron Div., General Offices, Fairfield, Ala.;** *Chicago Film Distribution Center,* **USS Public Relations Dept., 208 So. La Salle St., Chicago 90, Ill.;** *Cleveland Film Distribution Center,* **American Steel and Wire Div., Rockefeller Building, Cleveland 13, Ohio;** *New York Film Distribution Center,* **USS Corp., 71 Broadway, New York 16, N. Y.;** *Pittsburgh Film Distribution Center,* **USS Advertising Div., 525 William Penn Place, Pittsburgh 30, Pa.; and** *San Francisco Film Distribution Center,* **Columbia-Geneva Steel Div., 120 Montgomery St., San Francisco 6, Calif. Information on use of films outside the U. S. should be secured from** *United States Steel Export Co.,* **30 Church St., New York 8, N. Y.**

**A review of a few of the interesting films is given as follows:** *An Orchid to Mr. Jordan* **is a 16-mm (or 35-mm) sound color film which runs 25 min. This film shows the production of USS Stainless Steel, the fabrication of this metal, and how it makes contributions to health and better living.** *Sinews of the South,* **another 16-mm sound color film with a projection time of 34 min, is the story of the largest fully integrated steel producing company in the South. The film includes scenes from the ore and coal mines, quarries, conditioning plants, blast furnaces, open hearth furnaces, and operations in the various rolling and finishing mills. This film is available only from the** *Birmingham Film Distribution Center,* **and distribution is limited to the following states: Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, and Texas;** *Walls Without Welds* **is also a 16-mm (or 35-mm) sound color film with a running time of 28 min. Here for the first time are shown technicolor pictures made in the largest and most modern mills in the world devoted to the manufacture of tubular goods. The film includes views of the manufacture of large diameter seamless pipe showing the operations of the High-Mill, rotary rolling, reeling, sizing, and finishing.**

## PERSONALS

**Arthur S. Nowick,** formerly associate professor of metallurgy at Yale University, is now associated with the International Business Machines Corp. at their Watson Laboratory at Columbia University, New York.

**Raymond H. Filsinger Jr.** has been appointed vice president in charge of sales of Vanadium Corp. of America. Mr. Filsinger has been associated with the company since Feb. 1939.

**Edwin N. Hower** has accepted the position of vice president, Charles T. Brandt Inc., Baltimore, Md.

**F. A. Hames,** previously professor and head, dept. of metallurgy, Montana School of Mines, is now with the dept. of metallurgy, Queen's University, Kingston, Ontario.

**Francis J. Smit,** is now a graduate fellow at the Pennsylvania State University, University Park, Pa.

**Glenn D. Aase,** has accepted the position as air pollution engineer with the Bay Area Air Pollution Control District in San Francisco. Mr. Aase will be working largely with the metallurgical industries.

**Walter C. Troy,** formerly with the Hunter Engineering Co., Riverside, Calif., is now associated with the Malleable Research & Development Foundation, Granville, Ohio.

**Donald F. Stoneburner,** is on an educational leave of absence from the Oak Ridge National Laboratory where he is employed as an associate metallurgist. Mr. Stoneburner is working toward a Ph.D. degree in metallurgical engineering at the Carnegie Institute of Technology as the Union Carbide Corp. Fellow.

**John L. Merrill,** president of the Merrill Co., San Francisco, has been appointed a member of San Francisco's Redevelopment Agency.

**John R. Dunning,** dean of engineering of Columbia University, New York, has been elected to the board of directors of City Investing Co.

**Edgar W. Engle,** has been appointed development engineer for Kennametal Inc., Latrobe, Pa. Until recently, Mr. Engle was technical director for the Vascoloy-Rament Corp., Waukegan, Ill.

**Gotthard E. Björling,** has been appointed professor of nonferrous extractive metallurgy at the Royal Institute of Technology, Stockholm, Sweden.

**W. Rutherford,** has resigned his position of managing director of Melbourne Iron & Steel Mills Proprietary Ltd., Australia, and is now general manager and director of Allied Ironfounders Pty. Ltd., Victoria, Australia.

**J. E. Martiquet,** is now associated with Dalic Metachemical Ltd., Toronto, Canada. He formerly served with Canadian Pratt & Whitney Aircraft Co., Montreal.

**Joe G. Gonzalez,** has graduated from Texas Western College, El Paso, Texas, with a B. S. in geology and is now presently employed by The Anaconda Co. at Butte, Mont.

**Ralph Avellanet,** is now employed by the Electro Metallurgical Co. as an electric furnace production trainee.

**C. M. Schwitter,** formerly supervisor of Far Eastern and Latin American technical developments, has been promoted to head the market research activities of the International Nickel Co. Inc., New York. Mr. Schwitter will be assisted by **George Hoobler,** formerly a member of the steel section of the company's nickel sales dept.

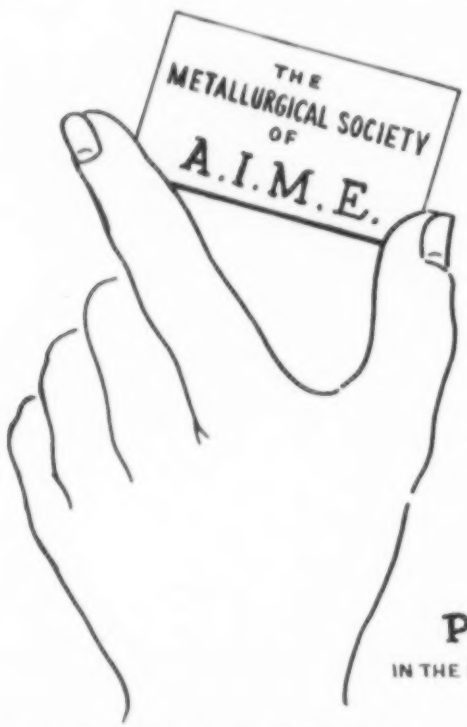
**R. D. Bradford,** vice president and director of American Smelting and Refining Co., has been placed in charge of the company's Federated Metals Div. Mr. Bradford will retain the presidency of Lake Asbestos of Quebec Ltd., ASARCO's new asbestos producing facility.

**David Turnbull,** manager of the chemical metallurgy section at the General Electric Laboratory, Schenectady, N. Y., is now in England for six months, studying and lecturing at the Cavendish, Laboratory, Cambridge University, under the new GE research leaves plan.

**F. W. Schroeder,** previously with North American Refractories Co. in Cleveland, is now located at the company's research center in Curwensville, Pa.

**G. Magnolo,** is now back with the sales engineering department, Linde Air Products Co., Toronto.

**Louis J. Demer** is currently with Rias Inc., Baltimore. He was previ-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ously at the Engineering Experimental Station, University of Minnesota, Minneapolis.

**Carl Ludwig,** has been promoted to chief engineer of the engineered products div., Wellman Engineering Co. Inc., one of the affiliates of McDowell Co. Inc., Cleveland.

**Victor A. Phillips,** has been appointed to the staff of the General Electric Research Laboratory in Schenectady, N. Y. Dr. Phillips formerly was a faculty member at the University of Sheffield in England.

**James H. Jacobs,** has been promoted to manager of the newly formed chemical engineering group in the product and process development dept., Electro Metallurgical Co., Niagara Falls, N. Y., a division of Union Carbide Corp.

**Kelvin Sproule,** previously consulting metallurgist for The International Nickel Co. of Canada Ltd. at Ontario, has been transferred to the development and research div. at the New York office.

**Alexander Troiano,** head of the metallurgical dept. at Case Institute of Technology, Cleveland, directed the concentrated two-day International Symposium on the Annealing of Low Carbon Steel held at Case, in which experts from six nations delivered a dozen papers on annealing processes during five general sessions.

**John H. Hoke,** has been appointed supervisor of the stainless steels section of the Crucible Steel Co. of America's Central Research Laboratory in Pittsburgh. Dr. Hoke was formerly associated with the Babcock and Wilcox Co. in Alliance, Ohio.

**Oleg D. Sherby** has now joined the staff of the Office of Naval Research, London Branch, as Scientific Liaison Officer in metallurgy, London, England.

**Donald A. Ricketts** and **Philip J. Hickey,** have been named to the posts, respectively, of general superintendent and assistant general superintendent of smelting and refining of the Sierra Div. of Cerro de Pasco Corp., Peru.

**Albert P. Spooner,** formerly chief metallurgical engineer of the steel division of Bethlehem Steel Co., has retired. The same company recently appointed **John S. Worth** and **Thomas G. Foulkes** as metallurgical engineers on the staff of S. J. Cort, operating vice president.

**George K. Williams** has terminated his residence in England and is now associated with the Consolidated Zinc Corp. Ltd., Melbourne, Australia.

**Gerald Abowitz** is now attending Yale University as a General Electric Fellow in metallurgy since his release from the U. S. Army.

**Martin G. Kurtz** is project engineer with the Pall Filtration Cos., Flushing, N. Y.

**K. Sudo** has left England and is currently at the Research Institute, Mineral Dressing Metallurgy, Tohoko University, Nagamachi, Sendai, Japan.

**Leonard Cogen** is now at Washington State College, Pullman, Wash.

## NECROLOGY

| Date Elected | Name | Date of Death |
|---|---|---|
| 1902 | A. B. Emery<br>Legion of Honor | July 26, 1957 |
| 1921 | Lincoln Johnson | Sept. 2, 1957 |
| 1949 | F. V. Richard | Sept. 5, 1957 |
| 1927 | A. Gonzales Soto | Mar. 2, 1957 |
| 1947 | Will M. Traver | March 1957 |

## OBITUARIES

**A. Gonzales Soto** (Member 1927) died March 2. Mr. Soto was born in Cangas de Onis, Spain, on Nov. 11, 1895 and was educated at the Academy of Artillery, Spain, and the School of Mines at Columbia University. Prior to his death, he resided in Madrid, Spain.

## MEMBERSHIP

*Proposed for Membership*
*Metallurgical Society of AIME*

*Total AIME membership on Sept. 30, 1957, was 28,317; in addition 3,155 Student Members were enrolled.*

*ADMISSIONS COMMITTEE*

*Harold K. Work, Chairman; Francis B. Foley; T. D. Jones; E. S. Machlin; J. H. Scaff; Paul Von Stein; T. B. Winkler.*

*The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.*

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## COMING EVENTS

**Nov. 2-8,** Second World Metallurgical Congress, Sherman Hotel, Chicago.

**Nov. 3-7,** AIME, IMD Fall Meeting Morrison Hotel, Chicago.

**Nov. 5,** AIME, Iron and Steel Division, Technical Sessions, Morrison Hotel, Chicago.

**Nov. 8,** AIME St. Louis Section, Hotel York, St. Louis.

**Nov. 12,** AIME, NOHC Buffalo Local Section, annual meeting, Royal Connaught Hotel, Hamilton, Ont., Canada.

**Nov. 13,** AIME San Francisco Section, Rickey's Studio Inn, Palo Alto, Calif.

**Nov. 14,** AIME Cleveland Section, President's Night, AIME President Grover J. Holt guest of honor, Carter Hotel, Cleveland.

**Nov. 18-21,** Conference on Magnetism and Magnetic Materials. Sponsors: AIEE in cooperation with AIME, American Physical Soc., IRE, ONR. Hotel Sheraton-Park, Washington, D. C.

**Nov. 20,** AIME Niagara Frontier Section, annual Frank J. Tone Award Meeting, Buffalo.

**Nov. 21,** AIME Utah Section, panel discussion: *Mining Industry: New Methods, Machines, and Materials.* Moderator, N. L. Weiss; panel, J. D. Moore, J. Rosenblatt, P. K. Richardson, H. Mathews.

**Nov. 26,** AIME Connecticut Section, student night, speaker: K. H. Mair, University of Rhode Island; subject: *Problems in Nuclear Metallurgy;* Town House, New Haven, Conn.

**Dec. 4-6,** AIME, 15th Electric Furnace Steel Conference, Penn-Sheraton Hotel, Pittsburgh.

**Dec. 11,** AIME Powder Metallurgy Group, New York Section, dinner meeting, Brass Rail Restaurant, New York.

**Dec. 11,** AIME San Francisco Section, Christmas party, Engineers' Club, San Francisco.

**Dec. 12,** AIME Utah Section, Salt Lake City.

**Dec. 13,** AIME St. Louis Section, ladies' night, Hotel York, St. Louis.

**Feb. 16-20, 1958,** AIME Annual Meeting, Statler and Sheraton-McAlpin Hotels, New York.

**Mar. 17-21,** EJC Nuclear Congress, International Amphitheatre, Chicago.

**Apr. 14-16,** AIME, 41st National Open Hearth Steel and Blast Furnace, Coke Oven, and Raw Materials Conference, Hotel Statler, Cleveland.

**May 5-6,** AIME, Conference on Properties of High-Strength Steel, Penn-Sheraton Hotel, Pittsburgh.

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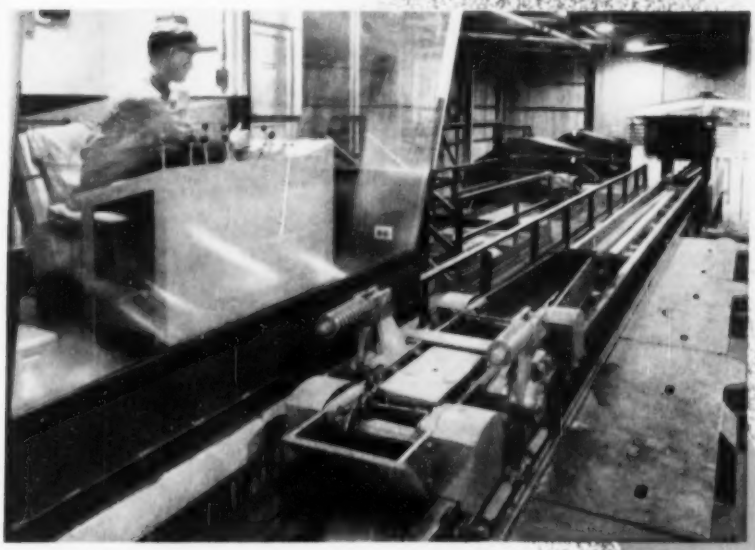

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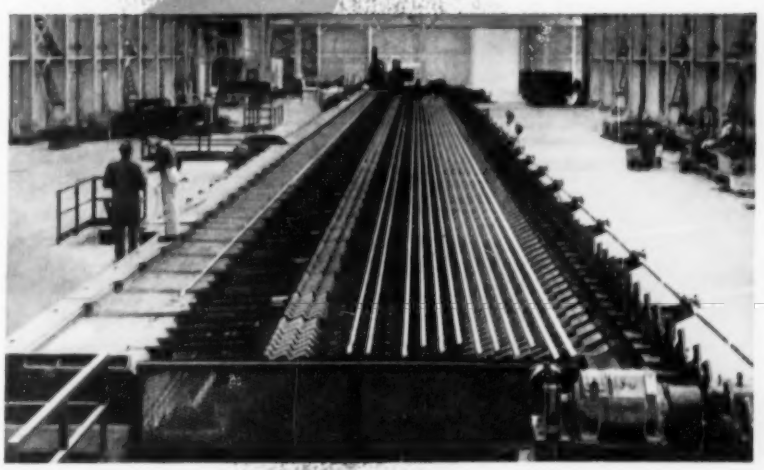

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